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A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATIONS OF COMPRESSED AIR

Vol. XI SEPTEMBER, 1906 No. 7

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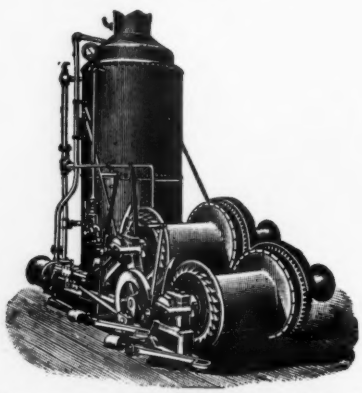

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COMPRESSED AIR
Established 1896.

A monthly magazine devoted to the useful applications of compressed air.

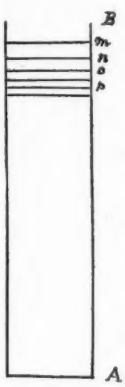
SEPTEMBER, 1906.

VARIATION IN ATMOSPHERIC PRESSURE WITH ALTITUDE.

WRITTEN FOR COMPRESSED AIR BY D. W. HERING.

In practice, a reference to standard tables often suffices for the engineer at least for approximate values of quantities, and too often a first approximation is as near the truth as he tries to get, but a table at best gives quantities that depend upon some one or more fundamental conditions, and is correct only for those conditions. An expert should know how to derive the table itself or the formula from which it is computed, and how to vary the table with varying initial conditions.

To determine the variation in atmospheric pressure with varying elevation:



Let AB represent a prism of air, 1 sq. ft. in area of cross section.

Let P_a, D_a represent the pressure and density, respectively, of air at the base of the column.

Let P, D represent pressure and density respectively at any point, m.

Let h represent the height of m above A.

Conceive the prism to be made up of successive very thin layers, as mn, no, op, etc., of equal weight w, and of variable height dh. For a given temperature, the pressure at any point is proportional to the density; or,

$$\frac{P_a}{P} = \frac{D_a}{D}, \text{ therefore}$$

$$\frac{1}{D} = \frac{P_a}{P}\,\frac{1}{D_a} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (A)$$

For any stratum of depth dh, the density is S, the volume in cubic feet is the area multiplied by the height, or $1 \times 1 \times dh$, and the weight is the increment of pressure; or $w = dP$. If w is pounds, the mass of one stratum is $\frac{w}{g}$, and the density being the ratio of mass to volume,

$$D = \frac{w}{g} \Big/ (1 \times 1 \times dh) \text{ whence}$$

$$dh = \frac{w}{g}\,\frac{1}{D} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (B)$$

Substituting for w its value dP and for $\frac{1}{S}$ its value from (A) we have

$$dh = \frac{P_a}{D_a g} \cdot \frac{dP}{P} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (C)$$

$$\text{Integrating } h = \frac{P_a}{D_a g} \int_{P}^{P_a} \frac{dP}{P} = \frac{P_a}{D_a g} \operatorname{Log} \frac{P_a}{P}$$

$$\text{or} \quad h = 2.303 \frac{P_a}{D_a g} \operatorname{Log}_{10} \frac{P_a}{P} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (D)$$

For uniform temperature throughout the column, the factor $2.303 \frac{P_a}{D_a g}$ is constant within the limits of height for which g may be taken as constant. Since the Pressure P_a here is in absolute units, $\frac{P_a}{g}$ is pounds, and by placing for $\frac{P_a}{g}$ the pressure in pounds per square foot, and for $\frac{1}{D_a}$ the volume in cubic feet per pound, then for a temperature of 32° F and under standard barometric pressure

$$\frac{P_a}{D_a g} = 26214$$

and equation (D) gives

$$h = 60360 \operatorname{Log}_{10} \frac{P_a}{P} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (E)$$

This equation gives the relation between the pressure, P, and the corresponding elevation, h, provided the air is at a temperature of 32° F. throughout. The ratio $\frac{P_a}{P}$ is equal to the relative barometer heights at the foot and at the top of the column of air, reduced to standard temperature in each case, but the

height of the column to produce either pressure will vary with the temperature of the air. The column may be assumed to have throughout a temperature which is the mean of that at the top and that at the bottom and, if this be called t° F, the height of the column will be the above value of h multiplied by $\frac{461 + t°}{493}$ or finally, calling the difference of elevation in feet between two points H,

$$H = 60360 \frac{461 + t}{493} \text{Log}_{10} \frac{P_a}{P} \quad \ldots\ldots \ldots (F)$$

From this formula, for any pressure P_a at a given station, and mean temperature t° of air column, the height H may be computed to correspond to a pressure P, or conversely the pressure P that would be found at a height H.

NOTE.—In strict accuracy the absolute pressures Pa and P, whether expressed in pounds weight, or in height of column of mercury, will depend for their numerical value upon the value of g; and this depends on both the latitude of the place and elevation above sea level. Assuming Pa to be the pressure for sea level at 45° represented by a certain height of mercury column, for the correct pressure elsewhere the barometer height would have to be multiplied by $(1 - 0.0026 \cos 2L = 0.00000006 h)$ in which L is the latitude and h is the altitude in feet; this factor is so near unity as to be negligible. For example, at the Equator, at the height of 20,000 feet the factor is .9962; at the Pole, at sea level, it is 1,0026; the total variation therefore between these extremes is the difference of these quantities, or .0064; that is less than two-thirds of one per cent.

If in equation (F) we take P_a as 14.7 lbs per square inch as at sea level, and assume for the mean temperature t, 50° F., the formula gives

$$\log 14.7 - \text{Log } P = \frac{493 \text{ H}}{511 \times 60360}$$

or $$\log P = 1.167317 - .000016 \text{ H} \quad \ldots\ldots (G)$$

In which P is absolute (not gauge) pressure in pounds per square inch, and H is feet. This is probably as simple a form as the equation can be put into. By assigning values to H and computing P the second column of Table 1 was obtained.

The third and fourth columns were obtained from equation (F) in the same manner by putting 35° and 20° instead of 50° for t. These can be represented by curves, but it is readily seen that a different curve is required for each temperature. The accompanying diagram shows the curves for 50° and 20°.

An empirical formula given by William Cox in COMPRESSED AIR for October, 1897, is

"Atmospheric pressure, A, at any elevation $= 14.72 - \frac{57000 - N_2}{100\,000\,000}$

where N is the elevation in feet at which the pressure A is sought" and A is pounds per square inch. This does not take account of temperature but gives values agreeing pretty closely with those computed above for 35° F

Elevation in feet.	PRESSURE IN POUNDS PER SQUARE INCH		
	Mean Temp. t = 50°	t = 35° F.	t = 20° F.
0 feet	14.7	14.7	14.7
1000	14.17	14.15	14.14
2000	13.66	13.63	13.59
3000	13.16	13.12	13.07
4000	12.69	12.63	12.57
5000	12.23	12.16	12.09
5280	12.1	12.03	11.96
6000	11.78	11.71	11.63
7000	11.36	11.27	11.18
8000	10.95	10.85	10.75
9000	10.55	10.45	10.33
10000	10.17	10.06	9.94
12500	9.28	9.15	9.02
15000	8.46	8.32	8.18
3½ miles	7.44	7.30	7.14

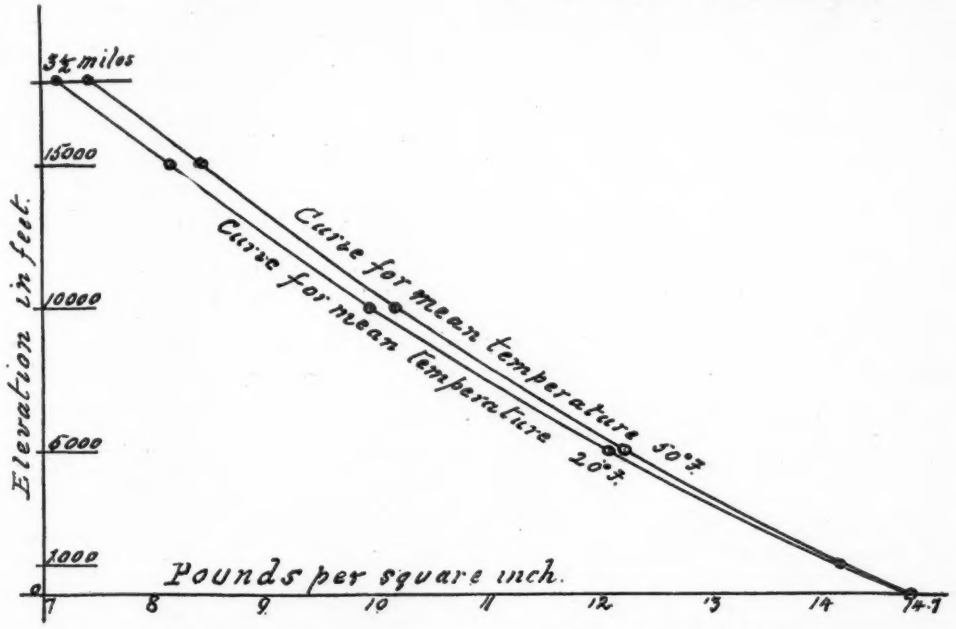
TABLE I.

A mean temperature of, say 50°, might mean 90° at the sea and 10° at the top, or it might mean 60° at sea level and 40° at the top. It is plain that the height of air corresponding to this mean temperature and therefore the height through which the tabular values for that temperature could apply would be much less in the latter case than in the former. For a given temperature at sea level the mean temperature for a column 1,000 feet high will be different from that for a column 10,000 feet high, so that a table based upon a given mean temperature will be correct only up to a height depending on the temperature at the base, or up to a prescribed height only for a proper temperature at the base.

Not only does the temperature fall as the elevation increases, but the rate at which it falls is not uniform; that is, it decreases more in the first thousand feet than in the second, and more in the second than in the third, and so on. A table, then, even if made out for numerous mean temperatures and a great variety of elevations, cannot be used intelligently without knowing how to select the proper temperature column of the table. It is obvious that a list of pressures correct for a mean temperature of, say 50°, could not be applicable at all when the temperature at the lower level is 50° or less.

A good general formula for changes of temperature with elevation may be obtained by reference to the snow line; i. e., the line below which all the snow is melted in midsummer. The elevation of this line, in general, between latitude 45° N, and 45° S, ranges from 12,000 to 18,000 feet above sea level. A suitable form of equation for the change of temperature is

$$T = T_0 e^{-\frac{H}{h}} \quad \ldots\ldots\ldots\ldots (H)$$



CURVES SHOWING VARIATION OF PRESSURE WITH VARYING ELEVATINO.

where H is any elevation above sea level, e the base of Naperian logarithms, T the temperature (absolute) at elevation H and T_0 the temperature at sea level. If we take T_0 = 80° F., (541° absolute) as mean sea level summer temperature to go with H = 16,000 feet as snow limit, for which T = 32°, (493° absolute), the formula reads $493 = 541\ e^{-\frac{16000}{h}}$ whence h = 172200. This makes the equation

$$T = T_0\, e^{-\frac{H}{172200}} \quad \ldots\ldots\ldots (J)$$

From this equation, by giving T_0 any value for the temperature at the lower level, the corresponding value of T for the height H may be determined, and therefore the proper mean temperature to use for a height H in the above table.

Suppose, for example, T^0 = 60° F., and we wished to reckon on a mean temperature of 50° as in the second column of the table. Through what range of elevation, H, would this extend? Since the lower temperature is 60° and the mean is 50° the upper temperature T must be 40° (501° absolute). Substituting these values in equation (J) we find H = 6,740 ft.

If, however, we wanted to know what changes of pressure to allow for through a height of 12,000 ft., with the mean temperature at sea level 60° F., these values in equation (J) give T=486° abs.=25° F., as the upper limit of temperature. This makes the mean temperature $\frac{60+25}{2} = 42°.5$ F., and the proper pressures could only be had from a table or a curve for this temperature.

Equation (J) leads to an interesting table of temperature-change from various sea level temperatures.

At Sea level	At 2500 ft.	At 5000 ft.	At 10000 ft.
32° F	25°.9	17°.9	4°.2
50°	42°.6	35°.4	21°.2
80°	72°.2	64°.5	49°.5
100°	91°.9	83°.9	68°.4

Table showing temperature at various heights, for different initial temperatures at sea level.

In applying equation (G) to a depth below sea level, H is a negative quantity, and log P is thus increased. For a mean temperature of 50°, as before, if H equals a depth of 2,000 feet, log P = 1.199317, whence P = 15.82 lbs. per sq. in. The pressure through this depth increases at very nearly a uniform rate with the depth $\frac{1.12}{14.7 \times 2000}$ part per foot. That is, the increase of pressure, and therefore of density, *for constant temperature* is .0000381 times the pressure at sea level for every foot of depth.

It is observed. however, that in general the temperature within the earth rises 1° F. for about every 60 ft. of depth. Since, for every degree rise of temperature under a given pressure the air expands, and therefore decreases in density by $\frac{1}{461 + t}$, this would tend to counteract the increase of density in descending into the earth, and in very nearly the same proportion as it would increase by reason of pressure; for if, as in the above example, the temperature at the surface is 50° F., then the density diminishes $\frac{1}{511 \times 60}$ part, or .0000326 per foot of depth by reason of rise in temperature. With air at 32° at sea level the proportional changes in density per foot of depth are,

Increase on account of pressure, .0000396.

Decrease on account of temperature, .0000338

These so nearly counteract each other that the actual change of density is only .000006 per foot of depth. Between surface temperatures of 20° and 80° this may be taken as an average fractional change in density per foot descent. An increase of .5 pound per square inch would be an increase of $\frac{.5}{14.7}$, or .034016, to effect which at the rate of .000006 per foot would require a depth of $\frac{.034016}{.000006}$, or 5 670 feet, or over one mile.

The effect of altitude on the efficiency of compressors may be briefly stated. If air at standard pressure of 14.7 pounds per sq. in., is compressed to G pounds per sq. in. gauge, its pressure is then G + 14.7, and when cooled to the initial temperature under this pressure, the volume will be $\frac{14.7}{G + 14.7}$ part of the volume of free air taken in by the compressor. If, by reason of elevation or other cause, the air initially is at a pressure of p pounds per square inch, and is compressed to the same gauge pressure, G, as before, then when cooled to the initial temperature its volume will $= \frac{p}{G + P}$ part of the volume of free air taken in by the compressor. For the same number of strokes this volume of free air will be alike in both instances; therefore the efficiency of the compressor working at an elevation as compared with its work at standard pressure will be the ratio of the volumes after compression, provided the air is at the same initial temperature in both cases. That is,

$$\text{Efficiency} = \frac{p}{G + p} \div \frac{14.7}{G + 14.7}$$

It must be remembered, however, that the gauge itself, on which the pressures are indicated, must read zero under the pressure of the atmosphere wherever it is used. If it does not its readings must be corrected for this error, for p and G + p stand for absolute pressures of the air before and after compression.

It is unnecessary to discuss this portion of the subject further here as it has been fully presented in COMPRESSED AIR; also in articles by William Cox, W. L. Saunders and F. C. Weber, in COMPRESSED AIR INFORMATION, pp. 98 to 105.

USES OF COMPRESSED AIR IN COAL MINES.*

BY J. L. DIXON, E. M.

The subject of this paper embraces a wide field which cannot be fully covered in an article of this kind, but as the majority of the members of this institute are acquainted with the ordinary applications of this power in coal mines, it will only be necessary to make a brief resume of this part of our subject, leaving the less known and proposed applications of compressed air for more extended discussion.

The production of coal is one of the most important industries of the world both in point of material value and in the part it plays in our modern civilization. I need not say that without it the wonderful achievements of the past century would not have been possible and the present enormous industrial activity impossible; coal is indeed "king" and apart from the soil is the most valuable material asset of this great country, but this like most things of value can only be won by toil, by courage, skill and perseverance, and the world owes a debt of gratitude to those brave men who have spent their lives in ceaseless endeavor to render this toilsome and perilous occupation less arduous and less dangerous.

The harnessing of natural forces to the direct production of coal came tardily, but once fairly commenced made rapid strides until now the machine mine is the rule and not the exception as it was a comparatively short time ago. In a few years 80 per cent. of all bitumin-

*A paper presented to the Mining Institute at Pittsburgh.

ous coal in this country will be produced by mechanical means, the motive power being compressed air and electricity; the former has no conflict with the latter, for there is a wide field of usefulness for both. We do propose to show, however, that the latter is an ideal power for underground work and is supreme in that province.

In the installation of compressed air plants at coal mines it has been and is still to a great extent the custom to install the cheapest class of machinery, boilers of low pressure, compressors of low efficiency, and pipe lines at haphazard, in many cases

SO WOEFULLY INEFFICIENT

as to render the whole installation practically useless. This power has been condemned by some mining men who have had experience with or who have visited plants of this kind without taking the trouble to go deeper into the matter. There has, however, been a radical departure from these lines in the last few years; in that time many large coal companies have installed plants where both boilers and compressors are of the most refined type and the fuel cost of production has been decreased over 100 per cent. A plant of this kind with ample pipe lines will show at the distant working face a favorable comparison of cost per unit of power with any plant of any kind ever installed.

The uses of compressed air in coal mining are as follows:

Haulage, by locomotives and by stationary engines.

Coal cutting and drilling, by percussive and rotary machines.

Pumping (as we have had an able paper on pumping, we will omit it from this).

Shearing in entries and rooms.

Proposed method of saving life, by and with compressed air.

Haulage, by compressed air, is the latest practical method which has been introduced into mines and is one which possesses many and peculiar advantages, amongst them being the following: Its almost absolute reliability and nearly total absence of repairs, its flexibility and safety under all conditions. That these are valuable features, none will deny.

It is not the intention to enter into a detailed description of a compressed air haulage plant. I will only outline the system and will quote from an article on this subject which I wrote some time ago:

"A compressed air haulage plant consists of a three or four-stage air compressor, capable of compressing air to 1,000 pounds pressure per square inch, locomotives of suitable weight and power, and constructed

TO CARRY STORED-UP ENERGY

in the shape of compressed air sufficient for requirements, suitable charging stations, a stationary reservoir ,which may be a pipe line, where long or diverging runs exist, or one or more storage tanks where the runs are short, the air being compressed in this storage system while the motor is making its trip, admitting of a small steady running compressor.

"The general mechanism of an air locomotive, cylinders, valve motion, frame, wheels, etc., is similar to the steam locomotive except that bearings are larger and every detail of construction stronger. The main points of difference are that, instead of the usual boiler and water accessories for developing steam power, the air locomotive is equipped with one or more strongly constructed storage tanks which are charged with compressed air to a high pressure, usually from 700 to 1,000 pounds per square inch, sometimes to 2,000 pounds. A combination regulator and automatic stop valve leading to the auxiliary low pressure reservoir in which the air is carried at a uniform working pressure usually 140 pounds, though greater pressures are available for emergencies. Relief valves make it impossible to charge the motor tanks to an unsafe or higher pressure than required, the initial storage pressure decreases while the locomotive is working, so there is never any risk from over-pressure, the dangers incident to the operation of a steam locomotive boiler, such as excess pressure, burnt crown sheets, fire boxes or flues collapsed from low water are entirely eliminated in the operation of a compressed air motor as the boiler and its accessories, which are the chief items of repairs and elements of danger, are replaced by air tanks which are practically indestructible.

"The locomotives are charged at stations located on the main line, the time consumed in charging including coupling and uncoupling being from one to two minutes. These locomotives are made to order, and

TO SUIT THE CONDITIONS

of the haulage, long, short, wide, narrow and low, to suit conditions.

"There are a dozen or more compressed air haulage plants in successful operation in Western Pennsylvania and a large number in the anthracite mines, any of which to those interested would well repay a visit."

If desirable, animal power can with this system of haulage be entirely eliminated, small motors of from three to four tons being used in the rooms; these can be run on either iron or wood rails, iron of course, being preferable.

Regarding the economy of this system, there can no longer be any doubt it has been a success in this and every other respect ever since its inception. Take, for instance, the very first plant introduced into the anthracite region in 1895, according to a report of the chief engineer of the company, the cost per ton mile, net weight, was 1.91 per ton, this figure being obtained by dividing the total operation expenses for two years, including fuel, labor, repairs, interest and depreciation, by the product obtained by multiplying the number of tons hauled by the motors during that time, by the average distance it was hauled in miles or fractions of miles. The difference of cost in favor of compressed air as compared with

mule haulage equaled the total cost of installation in 361 working days.

When it is taken into consideration that the plant was not worked much more than half of its capacity and that it was installed eleven years ago and paid for itself in so short a time, there can be no question as to its efficiency. Of course, the cost would differ with differing conditions; in some cases it would be higher and in many cases less. To sum up, it is a safe, flexible efficient,

RELIABLE AND ECONOMIC SYSTEM

of haulage, well worth your careful investigation.

Where the main haulage is rope, in some cases where animal power alone is relied on, stationary engines operated with compressed air are often used; for hauling coal out of dip entries or for hauling empty cars up any steep grades, the engines can be moved from place to place as occasion demands, and are very handy and useful where local dips abound.

Compressed air is playing a most important part in the mechanical production of coal, both percussive and rotary machines being driven by it. The puncher is the oldest and best known machine now in use, and in numbers far exceeds all other types combined; it is of exceedingly simple and durable construction, needing but few and inexpensive repairs. It is also a machine of wide adaptation and so flexible that it can be used under almost all conditions met with in coal mines. It has been in use for about twenty years during which time improvements have followed improvements until the pick machine of to-day is in simplicity, durability and cutting capacity almost as perfect as human skill can make it. It makes an undercut similar to that made by hand, which admits of easy blasting permitting the coal to roll forward, thus placing it in an ideal condition for loading, instead of merely dropping it an inch or so from the roof, as is the case with other machines. It cuts on the floor and does not leave three or four inches to be taken up by hand as the chain machine does. It can be used safely in bad roof where it would be extremely dangerous to use any other type. It can also be used to extract pillars, the chief necessity in this being the consent and concurrence of the mine boss. I have seen it used successfully in extremely bad roof for this purpose, and am sure it can be utilized in this work very much more than it is at the present time, if superintendents and foremen care to take the trouble of giving it their personal attention.

As most mining men are acquainted with the very simple mechanism and modus operandi of the puncher, it

WOULD BE WASTE OF TIME

to enter into a detailed description of either, so I will only say that this machine is for all around mining work, the simplest, cheapest, most durable, most flexible and most effective machine ever built. It is to-day producing seven-tenths of all machine mined coal in this country, and it will not only maintain this supremacy but join in the race, for it will be more than any other, better adapted to inevitable conditions which will prevail in the mining of the future.

The chain machine which is generally operated by electricity is also driven by compressed air, where conditions are suitable, that is to say, where the roof is good and the floor is level, and where the coal is free from sulphur balls, this machine does remarkably good work. The objections to it are mainly its bulk and weight, making the work of moving it around in the constricted mine space, extremely slow and laborious, its length making it necessary to leave an unpropped space of from 12 to 14 feet between the face and pole, the fact that it cuts above the floor and that the cut which is narrow and slot-like does not permit of effective blasting, or makes it imperative to blast so hard that the coal is much shattered. However, there are places where conditions are such that these objections are offset by the rapid cutting done by this machine, for in this respect it is superior to the percussive machine.

The principal point I wish to emphasize in this connection is that with compressed air either the percussive or rotary machine can be used, and as there are places in every mine where it is both desirable and profitable to use punching machines, that power which admits of the use of both now nearly approaches the practically ideal. This also holds true in the matter of drills and drilling for the percussive rock drill so indispensable in driving rock headings can only be operated by compressed air.

Considerable attention is now being paid to the perfection of a light, simple, portable rotary drill for drilling coal, slate and fire clay in mines. This seems to have been accomplished by a well known firm, in the shape of a machine which is a breast auger weighing 18 pounds and operated by compressed air. This is portable in the true sense and can be easily carried and operated by one man. I hope to see the time when these machines in the hands of experienced men will do all the drilling in our coal mines to the absolute

EXCLUSION OF DANGEROUS DRILLING

by inexperienced men, but of this, more hereafter.

Recently a machine of a new type has been perfected and placed on the market; many are in successful use where the conditions preclude the use of any other machine.

It is to all intents and purposes a long stroke rock drill mounted on a column, the mounting being specially adapted for coal mining work. The column may be of any length from two to eight feet. It is placed at right angles to the roof and floor about 3½ feet from the face and six feet from the rib in undermining or ten inches for shearing; it has a rosette on one end and a heavy jack screw in the other terminating in a rosette foot piece; a substantial block of wood is placed under the foot piece of the column and a piece of hard wood

about 2 inches thick is placed on top, the jack screw is then screwed as tight as possible. This operation need not consume more than five minutes, it is then ready for work. With one set up an undercut can be put in, in any part of the seam, 12 feet wide and any depth up to 8 feet, the average height of cut being 3 inches. This machine can be used and is used profitably in pitching veins, where the pitch is so great as to entirely preclude the use of any other machine. It is, of all machines of the percussive type, the easiest to run, there being absolutely no jar on the runner, his function being to guide the pick or bit and place the blows where they will do the most good.

I wish particularly to call your attention to this machine because of its efficiency in shearing and because the importance of shearing in coal mining has practically been lost sight of. Hitherto, there has not been any satisfactory mechanical means of doing this work, which may account in a measure for its almost utter lack in modern coal getting. I remember that when as a boy I worked in the English mines, no one was allowed to fire a shot in either entries or rooms without one rib being sheared. I remember also that my father worked at this one group of mines for nearly 40 years, part of the time as manager and there never was an explosion by blown out shots or otherwise, and some of the mines were very gaseous; had the same reckless, ignorant methods of blasting from the "face" which obtain here, been used there, the mining population would have been from time to time considerably

THINNED BY EXPLOSIONS

from blown-out shots. Explosions from this cause are multiplying with alarming rapidity and no remedy is being applied. There stands a monument not far from Pittsburgh but recently dedicated to the memory of 178 victims of a blown-out shot, the mine where this dreadful holocaust occurred is again at work, the same methods of blasting obtain as before, the same ignorant element handles the dangerous agent which together with dust and gas sent their predecessors to their narrow cells and long home. In a word all the elements and agencies necessary for a repetition of the awful disaster are potentially present, and as if this were not enough they are about to install that subtile power electricity, so dangerous in a gaseous mine, but there is no protest, no remedy suggested, yet the remedy is very obvious. There is nothing mysterious about a blown-out shot, it is simply a manifestation of carelessness or ignorance or both. The remedy, which should be enforced by law, and which would prove most effective, would be the absolute prohibition of any shot firing by any but approved and competent men and the enactment of a law compelling the shearing of both room and entries before blasting. The introduction of mining machinery has made quite feasible the employment of skilled men to do all the drilling and blasting most of which can be done at night, thus exposing fewer men to danger and rendering the mine safer and more sanitary during the day.

There will be, I have no doubt, many objections to a drastic measure of this kind and one of the objections will be that it will increase the cost of coal. That indeed would be a serious obstacle; there could be no greater in this age of selfishness and greed, which sacrifices human health and even life in its mad race for wealth.

The labor for drilling and blasting would average about one cent per ton, varying with conditions, shearing, because of the decrease in amount of slack and nut and shattered coal, would pay for itself and a

HANDSOME PROFIT WOULD ACCRUE

to the operator by the absence of blown-out shot disasters and by the approbation of his conscience for the establishment of a humanitarian regulation which does not cost him anything.

I think a question of this kind is worthy the attention of this body of representative mining men. It is your solemn and sacred duty to safeguard the lives placed under your care and you cannot contemplate without dire foreboding the ignorance and consequent recklessness of the modern mine crew. There is no other place or no industry on earth where the methods which obtain in some of our mines would be tolerated for an instant. In every industry where explosives are used except in coal mining, only experienced men appointed for that purpose are permitted to handle them, but in coal mines where the danger can hardly be overestimated or exaggerated and where the safety of all depends upon the skill and care of each one, men whose ignorance is monumental, are allowed to drill holes as they please, charge them as they please and fire them at their own pleasure. This is no figure of speech. I remember visiting a mine in company with the manager. The mine, which was in the first stages of development, was generating considerable gas; while in one of the entries, I noticed a polyandrous Slav ram a cartridge of such astounding proportions into a drill hole that I asked the manager as a special favor to allow me to get out of the shaft before the shot was fired, and incidentally suggested that he take all the rest out except the Slav. He laughed and said, "There is no danger." On arriving at the surface, I tried to convince him that there was very grave danger, but of course, he knew better. A few weeks after there was an explosion in this mine from a blown-out shot. Over a dozen men were killed. I regret to say that the name of the manager did not appear in the list.

While I have suggested a remedy for one of the most frequent causes of explosions, I wish also to suggest a method for the preservation of life after explosions in which compressed air is vitally essential, for after

HUMAN FORESIGHT AND SKILL

has exhausted every method and taken every precaution, it is safe to infer that explosions will still occur, for it seems as if there are causes mysterious and unknown, which set at defiance all human foresight and the deadly explosion takes place with all its attendant horrors.

In most explosions, the majority of those lost are asphyxiated by the after-damp. In numerous cases they have sufficient time to travel considerable distance before being overtaken and overcome by the deadly gas; in very many cases, men have lived for hours but at last their prison house becomes entirely devoid of life-giving oxygen, and they fall into that last sleep which knows no awakening. Had there been some definite point to which these men could have directed their steps where fresh air and food in abundance could be found, it is likely that the death list would have been diminished. It is singular that in most towns effective arrangements are made for the protection of life from fire, while all along the coast lines both of ocean and lakes, life-saving stations are established for the protection of the lives of those who go down to the sea in ships, yet nothing has been done for the preservation of the lives of those who work in perpetual danger and may at any hour be imprisoned deep down in the bowels of the earth.

The plan I wish to suggest is that in every mine, life saving stations or chambers of refuge should be established. They should be excavated in the solid coal, the approach should be by a long narrow entrance which could easily be rendered explosion proof. The chambers should be about 15 feet by 30 feet and should be connected with the surface by a compressed air line, which should be put down a bore hole directly into the chamber, or should be laid in the mine in such a way that

NO EXPLOSION WOULD DISTURB

it. This should be done by laying it in a ditch made for that purpose, of by covering it in such a manner that the line would not be broken by falls of rock. Connections should be made from this pipe into each chamber of refuge, which when turned on would give a sufficient supply of air to any refugees who may be so fortunate as to reach them. These chambers should be amply provided with first aids to the injured, with restoratives, with condensed foods, all in damp-proof cases. They should also be supplied with electric safety lamps, flasks of oxygen and with modern life saving appliances so that the safety chamber could be used as a base from which rescuers could go forth to the aid of those unable to reach the station. These places should also be connected with the surface by an explosion proof telephone system. This can be done by laying the wire in the compressed air pipe. It seems strange that while this remarkable invention is being used in nearly every artery of human industry, it should have been used so little in our coal mines. I will venture to say that there is not one explosion proof telephone system in any mine in the United States. How invaluable this would be to the imprisoned below and to those frantic with grief above, I need not say; just imagine what a blessing it would have been to many of the men entrapped in that large, French mine where over 1,300 were lost, making it the most disastrous accident in all mining history. There is evidence that hundreds of these men lived for days, some of them for over two weeks, even then still alive, living on the bark of props and on putrid horse flesh. When one reads of their awful sufferings, the heart turns sick with horror of it all. Had this mine been adequately supplied with safety chambers connected with the surface by compressed air and telephone, it is possible that hundreds would have been saved. They could have made their condition known to those above and a plentiful supply of cool, fresh air and of liquid food could have been transmitted to them, no matter how far away in the interior of the workings they might have been.

A system of this kind would

NOT BE EXPENSIVE TO INSTALL

and would be inexpensive to keep in order and in readiness for any emergency. In mines where compressed air is used, it could, by making the line explosion proof, be made part of the regular working system. A six or eight inch main line would insure a good supply of air for from two to three hundred men if confined to three or four safety chambers. The line can also be used for the transmission of liquid foods, as well as a conduit for telephone wires.

In order that the miners should have a guide to the safety station, arrows pointing in its direction should be made on the side of the entries with luminous paint, beacons pointing the way to present safety and eventually to wife, home and sunshine. Full instructions in every language represented in the mine should be printed and posted in conspicuous places. These instructions should fully set forth the uses of the system and under what conditions it is to be used. At each large mine, there should be a corps of trained men conversant with methods of life saving after an explosion, who could act with intelligent and efficient promptness. Let it be said to the deathless honor of coal miners everywhere that in case of an explosion, there are always volunteers ready to rush into the very jaws of death, and the history of coal mining is replete with deeds of the loftiest heroism before which the boasted exploits of chivalry pale into insignificance. Again and again rescue parties have descended into the yawning blackness of the pit, have met death in the noblest endeavor to save their comrades, often, I am sorry to say, acting

WITH MORE BRAVERY THAN JUDGMENT,

unnecessarily and unavailingly sacrificing their valuable lives. We should be prepared for explosions in our mines as we are prepared

for fires in our cities, for no man knoweth the day or the hour when these terrible disasters will send a thrill of horror throughout the world. The future of mining is fraught with grave dangers, each year our already enormous output will be increased; each year will mean more shafts, more gaseous mines, and unless more precautions are used, each year will add to our already too long list of disasters.

The conservative, thoughtful mining man cannot but view with alarm the manifest recklessness of many operators in introducing electricity into mines generating gas in dangerous quantities, thus increasing a danger which at the best is perilous enough. Compressed air is an ideal power under all conditions; it is efficient, economical, healthful and it is never a menace to valuable property, and still more valuable lives. It lessens the danger of explosions and in the event of one occurring, will be, if used as indicated, a very present help in time of trouble.

THE LATEST COMPRESSED AIR ENGINE.

The American Machinist, in a recent issue, gives an account, with the accompanying illustrations, of the *smallest* steam engine. It

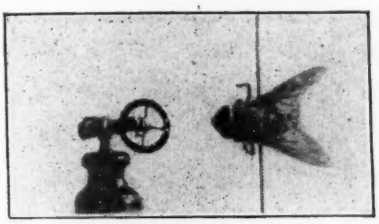


FIG. 1. THE ENGINE FULL SIZE.

can hardly be called a steam engine as it would not be practical to run it by steam and it is actually run by compressed air. As will be seen in Fig 2, it is an oscillating engine of simple design. The cylinder is .03 inch in diameter by .03125 inch stroke, and with 30

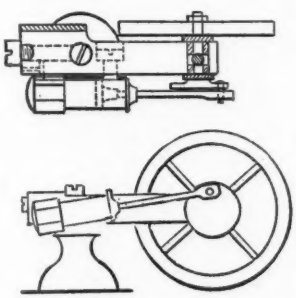


FIG. 2. THE CONSTRUCTION OF THE ENGINE.

pounds air pressure and an assumed mean effective pressnre of 20 pounds at the normal speed of 6,000 revolutions per minute, the horse power is .000013366. The free air consumption, with 15 per cent. added for clearance and leakage, is .0004109 cubic feet per minute. As the air is not reheated the best economy is not attained and indicator cards and data are not exhibited. Gold and steel are used in the construction, the flywheel, for instance, which was built up having a hub of steel and a rim of gold. Thos. H. Robinson, of Toronto, Ontario, built it.

ON THE MEASUREMENT OF AIR FLOWING INTO THE ATMOSPHERE THROUGH CIRCULAR ORIFICES IN THIN PLATES AND UNDER SMALL DIFFERENCES OF PRESSURE.*

BY R. J. DURLEY, MONTREAL, CANADA.

Introduction.

1. While engaged in experimental work requiring the measurement of quantities of air flowing at comparatively low pressures, the writer was led to an examination of the available formulae for the discharge of air under such conditions. These formulæ appeared to be insufficient for the purpose in view, and, after some preliminary trials, the experiments described below were made under the writer's supervision, in the Laboratories of the Department of Mechanical Engineering, McGill University, by Messrs. F. E. Sterns and G. M. Smith, Demonstrators in Mechanical Engineering.

2. In these experiments it was desired, first, to ascertain the laws governing the flow of air through circular orifices in thin plates at low heads; and, secondly, to measure the air discharged in such a manner that the experimental conditions could be easily duplicated at any time so that a similar gauging apparatus might be used in the laboratory.

3. Circular orifices bored in thin plates were selected because of simplicity of formation, and it was found that with proper apparatus, such orifices afforded a convenient means of gauging the amount of air discharged by fans, blowers, air engines, air compressors, and the like.

Existing Formulae.

4. The information generally available on the flow of air through orifices at low pressures may be summarized as follows:

*A paper read before the American Society of Mechanical Engineers.

(*a*) Weisbach's experiments*—These were made on air issuing into the atmosphere, and those made at low pressures gave the values of the coefficient of discharge for orifices 1 and 2.14 centimeter (0.39 and 0.84 inches) diameter when the ratio $\frac{\text{internal pressure}}{\text{external pressure}}$ had the values 1.05 and 1.09. This would correspond, with the barometer at 30 inches, to heads of 1.5 inches and 2.7 inches of mercury, or 22 inches and 37 inches of water nearly, and the coefficient of discharge (c) had values ranging from 0.555 to 0.589 in the formula.

$$v = c\sqrt{2gh},$$

where h is the head in feet of air.

(*b*) Fliegner's equations†—The empirical equation found by Fliegner as expressing results of experiments on the flow into the atmosphere from a reservoir in which the pressure is less than two atmospheres was:—

$$W = 1\ 060\ F\sqrt{\frac{p_a(p_1 - p_a)}{T_1}},$$

where W = weight passing in pounds per second.
F = area of orifice in square inches.
p_1 and p_a are absolute pressures in pounds per square inch.
T_1 = absolute temperature in degrees Fahr.

Calculation of Ideal Flow of Air Through an Orifice Under a Small Difference of Pressure.

5. The conditions under which the writer's experiments were carried out rendered it advisable to limit the head to 5 inches of water. It is therefore only necessary here to consider the formulae applying to the flow of air under low pressures—

6. Air at 32 degrees Fahr. and at a pressure of 14.7 pounds per square inch weighs 0.0807 pounds per cubic foot. At 60 degrees Fahr. the weight is therefore 0.0764 pounds nearly.. Under a pressure of five inches of water or 0.1505 pounds per square inch above atmospheric pressure, air at 60 degrees Fahr. would have a weight of $0.0764 \times \frac{14.8505}{14.7} =$ 0.0772 pounds per cubic foot, an increase in density of 0.0008 pounds, or say, 1 per cent. We shall see that this increase in density is so small that the air may be considered, without serious error, as remaining of uniform density during the experiments here described.

7. The consideration of the adiabatic flow of a perfect gas through a frictionless orifice leads to the equation*

$$W = A\sqrt{2g\frac{y}{y-1}\cdot\frac{P_1}{V_1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{y}} - \left(\frac{P_2}{P_1}\right)^{\frac{y+1}{y}}\right]} \quad (1)$$

In this expression
W = weight of gas discharged per second in pounds.
A = area of cross section of jet in square feet.
P_1 = pressure inside orifice in pounds per square foot.
P = pressure outside orifice.
V_1 = specific volume of gas inside orifice in cubic feet per pound.
y = ratio $Kp/Kv = \frac{\text{spec. heat at const. press.}}{\text{spec. heat at const. press.}}$ per pound.

For air, where $y = 1.404$, we have from equation (1) for a circular orifice of diameter d inches, the initial temperature of the air being 60 degrees Fahr. (or 521 degrees abs.),

$$W = 0.0816\ d^2\sqrt{\frac{P_1}{V_1}\left[\left(\frac{P_2}{P_1}\right)^{1.425} - \left(\frac{P_2}{P_1}\right)^{1.712}\right]},$$

or,

$$W = 0\ 000491\ d^2\ P_1\sqrt{\left(\frac{P_2}{P_1}\right)^{1.425} - \left(\frac{P_2}{P_1}\right)^{1.712}} \quad (2)$$

while, if we measure P_2 in lbs. per square inch,

$$W = 0\ 07058\ d^2\ P_1\sqrt{\left(\frac{P_2}{P_1}\right)^{1.425} - \left(\frac{P_2}{P_1}\right)^{1.712}} \quad (2a)$$

8. In practice the flow is not frictionless, nor is it perfectly adiabatic, and the amount of heat entering or leaving the gas is not known. Hence the weight actually discharged is to be found from such a formula as (2) by introducing a coefficient of discharge (generally less than unity) depending on the conditions of the experiment and on the construction of the particular form of orifice employed.

9. The above formula is not very convenient for calculation, and for practical purposes

* See Weisbach, "Der Civilingenieur," vol. 5, 1859, p. 546; also, "Theor. Mech.," 464-6 (5th American Edition), and "Peabody's Thermodynamics," p. 137. † See "Der Civilingenieur," vol. 20, p. 14.

*See note at end of paper, also "Peabody's Thermodynamics," p. 132. 081.

it is better (if the ratio $\frac{P_2}{P_1}$ is nearly unity) to employ a somewhat similar expression, obtained by assuming that the air or gas flows as would a liquid of the same mean density. In other words, we neglect the changes of density and temperature occurring as the air passes through the orifice, and are thus able to obtain a simpler though approximate formula—as follows:—

Let i = difference of pressure (between P_1 and P_2) measured in inches of water.

T = absolute temperature of air (supposed to remain unchanged).

U = velocity of air in feet per second (supposed uniform over whole cross section of orifice).

V = specific volume of air (supposed constant during passage through orifice).

P = mean pressure of air in pounds per square foot.

10. Then the head (measured in feet of air) under which the flow takes place is $h = V(P_1 - P_2)$.

But a pressure of one inch of water = 5.2 pounds per square foot, so that

$$h = 5.2\ i\ V.$$

Now $u = \sqrt{2gh}$ and the weight discharged per square foot of orifice per second will be

$$\frac{u}{V} = \sqrt{\frac{2g \times 5.2\ i\ V}{V}} = \sqrt{\frac{64.4 \times 5.2\ i}{V}}.$$

But $V = \frac{53.18\ T}{P}$ for air, so that the ideal discharge per square foot of orifice per second will be

$$\sqrt{\frac{64.4 \times 5.2\ i\ P}{53.18\ T}} = 2.509\sqrt{\frac{i\ P}{T}} \text{ pounds.}*$$

For an orifice of diameter d inches the ideal discharge will be

$$W = \frac{0.7854 d^2}{144} \times 2.509\sqrt{\frac{i\ P}{T}}$$

$$= 0.01369\ d^2\sqrt{\frac{i\ P}{T}} \quad \ldots\ldots\ldots (3)$$

In the usual case, in which the discharge takes place into the atmosphere, P is approximately 2,117 pounds per square foot and

$$W = 0.6299\ d^2\sqrt{\frac{i}{T}} \quad \ldots\ldots\ldots (4)$$

This equation is, of course, of the same form as Fliegner's well known formula.

11. It will be found that up to a pressure of about 20 inches of water (or 0.722 pounds per square inch) above the atmospheric pressure, the results of formulae (2) and (4) agree very closely. At higher differences of pressure divergence becomes noticeable. For example, if $P_1 - P_2 = 60$ inches of water or 2.166 pounds per square inch, we have from (4), if $P_2 =$ 2.117 pounds per square foot and $T = 60$ degrees Fahr.)—for a 3 inch orifice.

$$W = 06299\ d^2\sqrt{\frac{i}{T}} = 0.6299 \times 9 \times \sqrt{\frac{60}{521}}$$

= 1.892 lbs. per second. In the case of adiabatic expansion, from (2) we get

$$W = 0.0004901\ d^2\ P_1\sqrt{\left(\frac{P_2}{P_1}\right)^{1.425} - \left(\frac{P_2}{P_1}\right)^{1.712}}$$

$$= 0\ 00049011 \times 9 \times 2{,}422\sqrt{.8735^{1.425} - .8735^{1.712}}$$

$$= 0.00049011 \times 9 + 2.422 \times 0.1766$$

= 1885 lbs. per second.

The discharge as calculated by Fliegner's formula would be

$$1.06F\sqrt{\frac{P_2(P_1 - P_2)}{T}} = 1.06 \times 7.07 \times \frac{14\ 7 \times 2.166}{521}$$

$$= 1.06 \times 7.07 \times 0.2471$$

= 1.852 lbs. per second.

Even at the low pressures here considered Fliegner's rule gives results agreeing much more nearly with those of equations (2) and (4) than with the discharge actually measured. Thus for a 3 inch orifice we have:—

IDEAL DISCHARGE (pounds per second,	Head=1	2	3	4	5 ins of water.
By equation (4)....0.248	0 351	0.430	0 496	0.555	
By equation (2)....0.248	0.350	0.429	0.495	0.553	
Discharge by Fliegner's rule.....0.232	0.338	0.415	0.485	0.535	
Actual weight of air per second as found from experiments and curves.....0.149	0.210	0.257	0.296	0.331	

12. It is thus evident that the above formulae for the ideal amount of air discharged require the use of a coefficient of discharge in

* Thus when $P = 2{,}117$ lbs. per square foot and T is 521° (60° F.) the ideal discharge per second per square foot of orifice will be as follows:

i	1	2	3	4	5	inches of water.
W	5 060	7.155	8.764	10.12	11.312	lbs. per second.

order that the actual discharge may be computed by their aid, and to determine such a coefficient of discharge for a given orifice, it is necessary to measure the actual discharge and compare it with the amount calculated by such a formula as (2) or (4). These two formulae give results which differ so little within the limits of pressure here dealt with, that the latter has been chosen for use in this paper. Fig. 1 shows the ideal discharge calculated by the two formulae for a 3 inch orifice for various heads; their close agreement, within limits even greater than those of the experiments,

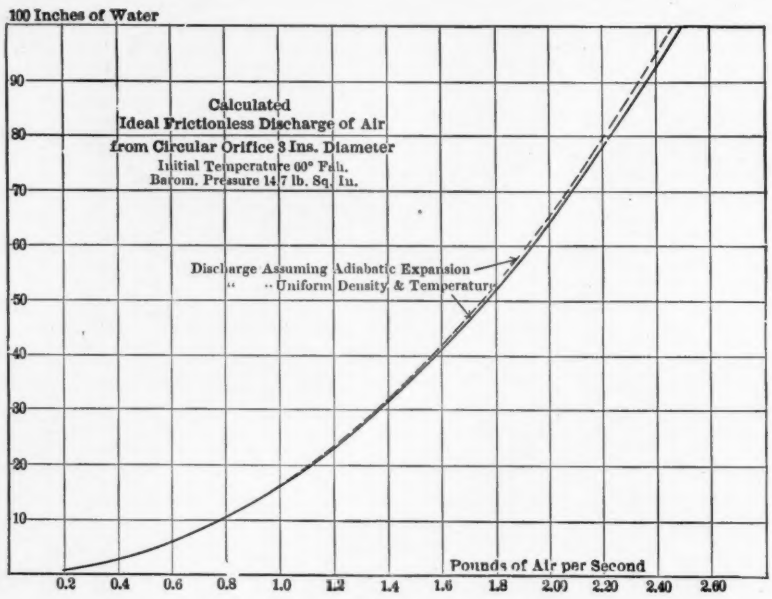


FIG. 1.

is evident.

13. The numbers given in table IV are the values of C in the expression,

Actual discharge in pounds per second

$$= 0.6299\ Cd^2\sqrt{\frac{i}{T}}$$

It is, of course, understood that they hold good only for orifices of the particular form experimented with, and bored in plates of the same thickness.

Scope of Experiments.

14. The largest air compressor available was a two stage belt driven machine capable of compressing about 350 cubic feet of free air per minute to a pressure of 100 pounds per square inch.—The air delivered by this compressor was stored in cast iron reservoirs whose combined volume was about 90 cubic feet. With this apparatus it was not found possible to discharge more than 8-10 of a pound of air per second without getting too rapid a fall of pressure in the reservoirs, and it was accordingly determined to limit the experiments to orifices less than 5 inches diameter and to work only with differences of pressure up to 5 inches of water. The data obtained, however, made it possible to continue the curves with reasonable accuracy so as to give coefficients of discharge for orifices up to, say, six inches diameter and for differences of pressure up to six inches of water.

Description of Apparatus and Methods of Experiment.

15. The general arrangement of the apparatus is shown in Fig. 2. The reservoirs R discharged into the gauging box B through a quick closing gate valve V_1 and a regulating valve V_2. After leaving these valves the air passed at low pressure through a heater H, consisting of a number of thin sheet iron boxes immersed in a tank of water whose temperature could be varied as desired.

16. The gauging box, shown in detail in Fig. 3, was of 1 inch pine made air tight by pitch on the inside. It was 6 feet long and 10

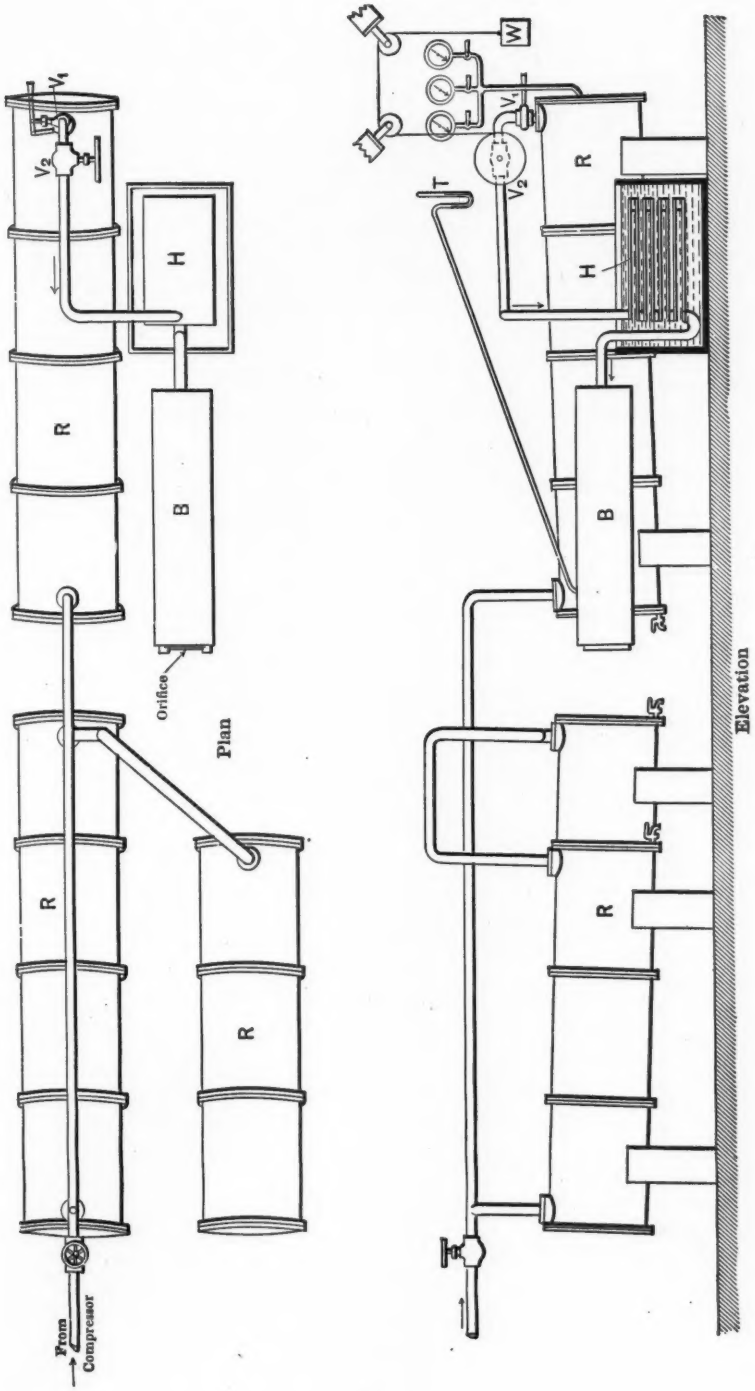


FIG. 2.

inches by 10 inches inside dimensions. Near the end at which the air entered, suitable baffle plates were placed as shown. The connection for the U tube for measuring the head was placed near the middle of the box.

17. The air reservoirs (*R*, Fig. 2) were built up of cylindrical flanged castings connected by bolts. The joints were made with asbestos millboard, soaked in boiled oil, and as it was necessary to use fairly high pressure in the reservoirs in order to get experiments of sufficient length on large orifices, some difficulty was experienced in keeping the joints tight. The leak was carefully measured and it was found that at the highest pressure it did not exceed 0.0005 pounds per second, while at low pressure its amount was negligible. The results of the leak tests were correct to within at least 10 per cent., and therefore the greatest possible error made in allowing for the leak would be 0.00005 pounds per second, not more than 3 per cent. of the whole discharge on the 5-16 inch orifice, and decreasing to 1-100 of 1 per cent. on the 4 inch orifice.

18. The orifices were carefully bored in iron plates No. 15 Brown & Sharpe Wire Gauge (0.057 inch thick), and were true to size within 5-1,000 inch. In calculating the ideal discharge, the size measured correctly to within 1-1,000 inch by a vernier caliper, was used in each case. The effect on the result due to inaccuracy in measurement of orifice diameter would therefore not exceed 7-10 of 1 per cent., on the 5-16 inch orifice, while on the 1 inch orifice it would be less than 1-5 of 1 per cent., and on larger orifices would be smaller still.

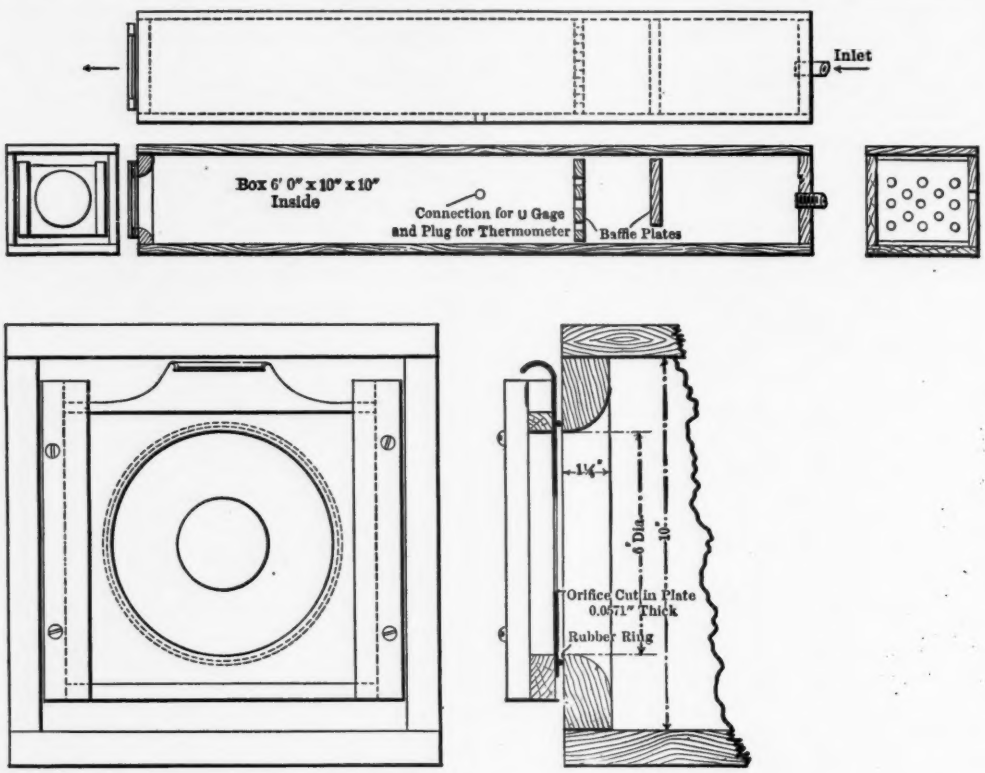


FIG. 3. DETAILS OF GAUGING BOX AND ORIFICE.

19. The orifice plates were secured to the end of the box in such a way as to be easily removed and interchanged. The joint between plate and box was made tight with rubber cord.

20. The temperature of the air in the box was measured by a thermometer placed near the middle of its length. This reading was checked at intervals by means of a thermometer suspended lengthwise in the jet, and was

never found to vary more than one-tenth of 1 per cent. from the actual absolute temperature in the orifice, except in the high temperature trials. In these trials three thermometers placed at different distances from the orifice were used and from their readings the actual temperature in the orifice was deduced.

21. Standard mercury thermometers were used to measure the temperature of the air in the reservoir. They were inserted through rubber packer stuffing boxes so that the bulb came into actual contact with the air and was therefore exposed to the pressure in the reservoir. This pressure increased the reading about 1 degree for every 100 pounds, which was allowed for correctly to within 0.05 degree. The thermometers were graduated in degrees and tenths Fahr., and were such that temperatures read from them were correct to within 0.1 degree. The error on 500 degrees (the approximate absolute temperature) would therefore be less than 0.03 of 1 per cent.

22. For measuring the pressure in the gauging box, the U tube T (Fig. 2) was placed in a convenient position for the eye of the person operating the regulating valves and was connected to the box by rubber tubing. A scale of half inches divided on blackened glass was placed behind one leg of the U tube so as to read inches of head, and was illuminated by an incandescent light suspended behind it. To avoid parallax the scale was read through a small telescope fastened with a clip so as to slide up and down the leg of the U tube. The scale was graduated correctly to within 2-1,000 inch; the resulting possible error would therefore not exceed 4-10 of 1 per cent. on the 1 inch head and would be about 1-10 of 1 per cent. on the 4 inch head. As the meniscus was magnified considerably by the telescope, the error in reading its position would probably not be more than 2-1,000 inch, leading to an error of the same amount as that just mentioned, in the final result.

23. The pressure in the reservoir was measured by Standard Crosby gauges which were carefully calibrated on the dead weight gauge tester. On trials on the smaller orifices a gauge graduated in pound per square inch was used. This gauge could be read correctly to within 1-10 of a pound per square inch, parallax being avoided by aligning the pointer with its shadow thrown on the dial by a small lamp suspended opposite the center of the gauge. Where the difference between the initial and final pressures was not less than fifty pounds per square inch, the error would not exceed 1-5 of 1 per cent. As it was very difficult to keep the head constant when the reservoir pressure became low in trials on the larger orifices, the range of pressure was shortened for these trials, and gauges graduated in tenths of a pound were then used, giving readings correct to 0.02 pound, so that the error on a range of twenty pounds would not exceed 1-10 of 1 per cent.

24. The reservoirs were provided with drain cocks so that water condensing from the vapor in the air pumped in could be drawn off. The drains were opened so frequently that never more than a pound of water was collected, which would make an error of less than 1-40 of 1 per cent. on a reservoir volume of 90 cubic feet.

25. In certain trials on the smaller orifices, a small wrought iron reservoir (volume 4.294 cubic feet) was used with the object of getting a wide range of pressure in a short time. and also of checking results obtained from the large reservoir. From this reservoir there was no leak, and other errors were of the same order as those previously mentioned.

26. As mentioned above, some difficulty was experienced in keeping the pressure uniform in the gauging box when the discharge was great. This was partially remedied by stopping the trial before the pressure in the reservoir had fallen too low. It was almost completely obviated by attaching to the spindle of the regulating valve a grooved pulley and leading a cord from its rim over guide pulleys to a weight (W, Fig. 2) of about ten pounds. It was then found that the valve could be opened much more uniformly by resisting the action of the weight than by moving the valve wheel directly. By this means the fluctuations were reduced to less than 2 per cent. of the head, and the trials were so long that the error in measuring the head was substantially only that already mentioned due to inaccurate reading and to imperfect graduation of the scale.

27. Time was measured on some of the trials by an ordinary watch, on others by a stop watch, and on others by a recording chronograph. The ordinary watch was used on trials of 5 minutes duration and longer, and as it could be read correctly to within half a second, the error in an experiment last-

ing 20 minutes would not exceed 0.08 of 1 per cent. On trials of two or three minutes the stop watch was used with an error less than 1-6 of 1 per cent. The chronograph, which made its records automatically, was used on trials of less than two minutes duration and gave readings correct to within 1-50 second. As the shortest trial occupied at least 30 seconds, the error would not be greater than 1-15 of 1 per cent. The trials were started and stopped by means of a quick opening gate valve *V* (Fig. 2), placed between the regulating valve and the reservoir, the chronograph circuit being closed as the handle of the gate valve passed its mid position.

28. The volume of the reservoir was measured by weighing the amount of water necessary to fill it. The water was weighed in tanks holding 100 pounds, on scales reading correctly to half an ounce, so that the error could not exceed 1-16 of 1 per cent. The total volume of the three parts of the reservoir and the piping was found to be 91.881 cubic feet. The various errors just discussed are enumerated in Table I.

(*To be Concluded.*)

TABLE I.

SOURCES OF ERROR.

OPERATION.	ERROR IN PER CENT.	
	5/16-inch Orifice. 1-inch Head.	4-inch Orifice. 4-inch Head.
Allowing for leak	±3.0	±0.01
Reading pressure in reservoir	±0.2	±0.2
Reading temperature in reservoir	±0.03	±0.03
Finding volume of temperature in reservoir	±0.07	±0.07
Allowing for condensed water in reservoir.	−0.025	−0.025
Measuring area of orifice	±0.7	±0..05
Taking temperature in box	±0.1	±0.1
Graduating *U* tube	±0.4	±0.1
Reading from tube	±0.4	±0.1
Measuring time	±0.08	±0.06

TABLE II.

EXPERIMENTS SHOWING EFFECTS OF TEMPERATURE OF AIR.

Diameter of orifice, 1 inch. Difference of pressure, 3 inches of water.

1	2	3	4	5	6
Expt. No.	Temperature in Gauging Box. Deg. Fahr., abs.	Actual discharge as measured. Lbs. per Second.	Corrected discharge as taken from curves. Fig. II. Lbs. per Second.	Square Root of abs. Temperature.	Product Column 5 × Column 4
151	516.1	0.02938	0.02910	22.72	0.6612
152	525.5	0.02901	0.02895	22.92	0.6632
153	525.9	0.02934	0.02893	22.93	0.6634
154	526.3	0.02881	0.02890	22.94	0.6630
155	537.0	0.02827	0.02860	23.17	0.6627
156	542.4	0.02864	0.02850	23.29	0.6638
157	546.8	0.02832	0.02835	23.38	0.6628
158	548.1	0.02984	0.02830	23.41	0.6626
159	549.6	0.02767	0.02825	23.45	0.6625
160	561.8	0.02637	0.02795	23.70	0.6624
161	563.3	0.03004	0.02790	23.73	0.6621
162	567.6	0.02636	0.02775	23.82	0.6610

TABLE III.

MEAN DISCHARGE IN POUNDS PER SQUARE FOOT OF ORIFICE PER SECOND, AS FOUND FROM EXPERIMENTS.

Diameter of Orifice. Inches.	1-inch Head Discharge per Sq. Ft.	2-inch Head Discharge per Sq. Ft.	3-inch Head Discharge per Sq. Ft.	4-inch Head Discharge per Sq. Ft.	5-inch Head Discharge per Sq. Ft.
0.3125	3.060	4.336	5.395	6.188	7.024
0.5005	3.012	4.297	5.242	6.129	6.821
1.002	3.058	4.341	5.348	6.214	6.838
1.505	3.050	4.257	5.222	6.071	6.775
2.002	2.983	4.286	5.284	6.107	6.788
2.502	3.041	4.303	5.224	5.991	6.762
3.001	3.078	4.297	5.219	6.033	6.802
3.497	3.051	4.258	5.202	5.966	6.814
4.002	3.046	4.325	5.264	5.951	6.774
4.506	3.075	4.383	5.508	6.260	7.028

TABLE IV.

COEFFICIENT OF DISCHARGE FOR VARIOUS HEADS AND DIAMETERS OF ORIFICE.

Diameter of Orifice. Inches.	1-inch Head.	2-inch Head.	3-inch Head.	4-inch Head.	5-inch Head.
5/16	0.603	0.606	0.610	0.613	0.616
½	0.602	0.605	0.608	0.610	0.613
1	0.601	0.603	0.605	0.606	0.607
1½	0.601	0.601	0.602	0.603	0.603
2	0.600	0.600	0.600	0.600	0.600
2½	0.599	0.599	0.599	0.598	0.598
3	0.599	0.598	0.597	0.596	0.596
3½	0.599	0.597	0.596	0.595	0.594
4	0.598	0.597	0.595	0.594	0.593
4½	0.598	0.596	0.596	0.593	0.592

Weight of air discharged per second $= 0.6299\ Cd^2\sqrt{\frac{i}{T}}$ lbs. (Barometer at 30 inches.)

TABLE V.

CORRECTED ACTUAL DISCHARGE IN POUNDS PER SECOND AT 60 DEGREES FAHR. AND 14.7 POUNDS BAROMETRIC PRESSURE FOR CIRCULAR ORIFICES IN PLATE 0.057 INCHES THICK.

Head Inches	DIAGRAM OF ORIFICE IN INCHES										
	0.3125	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500	5.000
½	0.00114	0.00293	0.0117	0.0263	0.0468	0.0732	0.105	0.143	0.187	0.237	0.292
1	0.00162	0.00416	0.0166	0.0373	0.0663	0.103	0.149	0.202	0.264	0.334	0.413
1½	0.00199	0.00510	0.0203	0.0457	0.0811	0.127	0.182	0.248	0.323	0.409	0.505
2	0.00231	0.00590	0.0235	0.0528	0.0937	0.146	0.210	0.285	0.373	0.471	0.582
2½	0.00259	0.00662	0.0263	0.0591	0.105	0.163	0.235	0.319	0.416	0.526	0.649
3	0.00285	0.00726	0.0289	0.0648	0.115	0.179	0.257	0.349	0.455	0.575	0.710
3½	0.00308	0.00786	0.0312	0.0700	0.124	0.193	0.277	0.377	0.491	0.621	0.766
4	0.00330	0.00842	0.0334	0.0749	0.133	0.206	0.296	0.402	0.525	0.663	0.817
4½	0.00351	0.00895	0.0355	0.0794	0.141	0.219	0.314	0.426	0.556	0.702	0.865
5	0.00371	0.00945	0.0375	0.0838	0.148	0.231	0.331	0.449	0.586	0.739	0.912
5½	0.00390	0.00993	0.0393	0.0879	0.155	0.242	0.347	0.471	0.613	0.774	0.953
6	0.00408	0.01049	0.0411	0.0918	0.162	0.252	0.362	0.492	0.640	0.808	0.995

TABLE VI.

No. of trial.	Diam. of Orifice ins.	Head ins. water	Duration of trial. Secs	Reservoir				Box Temp. Abs.	Actual discharge Lbs. Sec	Corrected actual discharge at 60° F. and 14.7 lbs.
				Abs. Pressures		Abs Temperature				
				Initial.	Final.	Initial.	Final.			
1	5/16	1	1,260	88.8	83.4	520.1	520.0	518.6	.002033	.001628
2	"	1	3,900	95.4	78.7	520.1	520.0	518.5	.002040	.001631
3	"	2	1,200	71.8	64.8	519.9	519.8	520.0	.002758	.002430
4	"	2	3,600	78.2	58.7	520.0	519.8	520.0	.002592	.002264
5	"	2	508	78.2	19.4	542.8	531.5	534.0	002463	.002236
6	"	3	1,200	57.6	49.7	520.0	519.8	521.0	.003149	.002879
7	"	3	1,200	49.7	41.8	519.8	519.8	521.3	.003152	.002912
8	"	3	3,600	57.6	34.5	520.0	519.8	521.3	.003072	.002832
9	"	4	1,800	92.14	78.22	520.9	520.6	521.4	.003677	.003292
10	"	4	1,560	78.22	66.31	520.6	520.5	520.5	.003637	.003296
11	"	4	4,080	92.14	60.79	520.9	520.4	520.2	.003665	.003262
12	"	4	373	92.5	27.6	542.3	530.6	531.2	.003699	.003333
13	"	5	2,400	59.9	39.8	520.4	519.9	521.5	.003998	.003748
14	"	5	2,700	101.18	77.39	522.1	520.1	522.2	.004157	.003751
15	"	5	3,900	101 18	67.27	522.1	520.5	522.3	.004109	.003723

TABLE VII.

No. of trial.	Diam. of Orifice ins.	Head ins. water	Duration of trial Secs.	Reservoir				Box Temp. Abs.	Actual discharge Lbs. Sec.	Corrected actual discharge at 60° F. and 14.7 lbs.
				Abs Pressures.		Abs. Temperature				
				Initial.	Final.	Initial.	Final.			
16	½	1	3,398	96.8	63.7	529.2	523.4	524.5	.004482	.004123
17	"	1	1,153	96.8	85.0	529.2	524.0	524.4	.004468	.004067
18	"	1	2,245	85.0	63.7	524.0	523.4	524.5	.004489	.004155
19	"	2	2,427	96.8	64.7	524.9	522.6	524.4	.006227	.005869
20	"	2	1,276	96.8	79.9	524.9	523.2	524.4	.006200	.005822
21	"	2	1,151	79.9	64.7	523.2	522.6	524.1	.006247	.005924
22	"	3	2,992	103.0	54.6	528.8	523.1	524.9	.007518	.007177
23	"	3	1,081	103.0	85.0	528.8	524.1	524.5	.007482	.007078
24	"	3	1,911	85.0	54.6	524.1	523.1	525.0	.007541	.007236
25	"	4	2,126	93.8	54.6	525.3	522.9	523.4	.008674	.008346
26	"	4	1,036	93.8	74.7	525.3	523.5	523.0	.008600	.008322
27	"	4	1,090	74.7	54.6	523.5	522.9	523.8	.008744	.008457
28	"	5	981	94.8	74.7	526.4	524.6	518.9	.009561	.009185
29	"	5	533	65.7	54.6	524.3	522.8	521.1	.009757	.009457

TABLE VIII.

No. of trial	Diam. of Orifice ins.	Head ins. water	Duration of trial. Secs.	Reservoir				Box Temp. Abs.	Actual dischatge Lbs. Sec.	Corrected actual discharge at 60° F. and 14.7 lbs.
				Abs. Pressures.		Abs. Temperature				
				Initial.	Final.	Initial.	Final.			
30	1	1	412	87.0	72.5	522.6	521.0	519.1	.01643	.01603
31	1	1	833.67	94.17	63.39	522.1	521.4	513.8	.01752	.01699
32	1	1	870.14	93.51	60.90	521.1	518.8	515.5	.01773	.01723
33	1	2	1,157	92.1	32.6	529.5	518.0	520.0	.02389	.02357
34	1	2	587	62.5	32.6	519.6	518.0	520.2	.02432	.02406
35	1	2	1,147	92.1	32.6	533.1	518.2	520.4	.02384	.02353
36	1	2	587	62.5	32.6	520.0	518.2	520.1	.02424	.02398
37	1	3	478	60.5	30.6	520.1	518.6	522.1	.02984	.02963
38	1	3	748	83.9	36.5	524.5	520.6	521.7	.02990	.02963
39	1	3	1,020	91.3	27.5	522.6	518.2	516.1	.02967	.02925
40	1	4	676	94.8	44.8	523.4	517.0	520.1	.03477	.03440
41	1	4	658	94.8	44.8	535.8	517.4	524.6	.03415	.03393
42	1	4	776	91.8	34.6	528.8	515.4	519.8	.03414	.03379
43	1	5	593	94.8	44.8	588.8	518.5	518.5	.03758	.03715
44	1	5	588	94.8	44.8	537.9	518.3	518.8	.03798	.03756
45	1	5	587	94.8	44.8	538.0	518.3	518.7	.03806	.03764

COMPRESSED AIR

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CONTENTS.

Variation in Atmospheric Pressure with Altitude 4173
Uses of Compressed Air in Coal Mines.. 4176
The Latest Compressed Air Engine..... 4181
On the Measurement of Air Flowing into the Atmosphere through Circular Orifices in Thin Plates and Under Small Differences of Pressure..... 4181
Editorials:—
Refuge Chambers in Coal Mines. Denatured Alcohol Again. Superheated Steam..... 4191
Engineering Times in New Form..... 4193
Trade Publications..... 4193
Industrial:—
Comparative Test of Large Locomotive Air Pumps. A new Compressed Air Computer..... 4194
Practical Items for Practical Men..... 4202
Chippings..... 4203
United States Patents..... 4205
Office Chit-Chat..... 4207

REFUGE CHAMBERS IN COAL MINES.

We publish in this issue a paper read by Mr. J. L. Dixon, E. M., at the meeting of the Mining Institute of Pittsburg, June 20th last. Mr. Dixon has written very intelligently upon the subject, "Uses of Compressed Air in Coal Mines." Anything on this subject from Mr. Dixon is of interest and value because of its practical nature. Mr. Dixon is an engineer thoroughly familiar with coal mining, especially in connection with power plants. He does not attempt to claim everything for compressed air, but he specifies those special uses of compressed air which have made it so invaluable in coal mining. For instance, haulage, by locomotives and by stationary engines, coal cutting and drilling by percussive and rotary machines, pumping, shearing in entries and rooms, and to those useful applications, with which most mining engineers are familiar, he adds the "Proposed method of saving life by and with compressed air." This suggestion has the virtue of novelty and it is worthy of the serious consideration of mining men.

It is proposed to equip every mine with life-saving stations or chambers of refuge. These chambers might be excavated in the coal and approached by long, narrow entrances which could easily be rendered explosion proof. The chambers are to be connected with the surface by a compressed air line, which can be put down a bore hole directly into the chamber. It has recently been found that rotary core drills which are capable of boring holes of large diameter, and without the use of diamonds are especially suited for boring entry holes into mines, and there appears to be no difficulty in the way of a special compressed air pipe line leading to these refuge chambers and serving to keep them supplied with fresh air in the event of an explosion. To save one life by a safeguard of this kind would in itself warrant the expenditure, and we trust that those interested in the subject will read all that Mr. Dixon has to say and that they will aid in putting the suggestion to practical use.

DENATURED ALCOHOL AGAIN.

In recent issues of COMPRESSED AIR we have devoted considerable space to the subject of denatured alcohol, its possible future and methods of manufacture. Now comes word from the Department of Agriculture that an investigation into the possibilities of alcohol as

a fuel in small gas engines is about to be carried out by Prof. Chas. E. Lucke, of Columbia University, New York City, as a result of the passage of the bill allowing the sale of alcohol without the internal revenue tax. The Department of Agriculture has decided to publish a bulletin on the first of January next, when this law goes into effect, giving the public a collection of the best obtainable data on the use of denatured alcohol as a motive power in internal combustion engines. For this purpose it has retained Prof. Lucke as the department expert to conduct the necessary investigations in the laboratories of Columbia University.

When this law goes into effect very large quantities of denatured alcohol will be used as fuel in automobiles, boats, and for stationary work. The advantages of alcohol for these purposes are numerous, especially the lack of odor in combustion and safety from fire over kerosene or gasolene, because it is possible to put out an alcohol fire with water, where it is impossible to extinguish either of the others in this way.

In spite of the fact that a great deal has been done to secure the passage of the bill there is very little information of value on the subject to be found. Prof. Lucke will collect the results of the experiments conducted on the use of alcohol in engines which have been carried out both here and abroad and will expand the information by further experiments, inviting all those who have patents on vaporizers, carburettors or complete engines to submit the apparatus to tests in his laboratory. These tests will be conducted without any expense whatever to the public, except the transportation of apparatus, the reports of the test being published in the before mentioned bulletin. Any data or shipments should be addressed to Prof. Chas. E. Lucke at Columbia University, and they will be returned when the work is completed, due acknowledgement being given for the assistance rendered. It is to be hoped that, should any of our readers possess apparatus of this nature, that they will take advantage of this offer.

SUPERHEATED STEAM.

We note in a recent issue of the *Engineering Record* a very able editorial on the subject of superheated steam in which are brought out points of which very few people possess a clear understanding. For instance, not many engineers realize that the improvement in economy from the use of superheated steam is not due, except in very small measure, to the mere fact of increase in temperature in the steam fed to the engine, or to the influence of such increase in temperature on what is commonly known as the thermodynamic or ideal efficiency of the engine. One of the erroneous views which has occasionally misled engineers is that the improvement in economy traces back to the familiar law of thermodynamics which expresses the economy of the ideal Carnot cycle in the form $(T_1 - T_2) \div T_1$ where T_1 and T_2 are the upper and lower temperatures of the isothermal paths along which all the heat is either received or rejected. Reasoning then that superheating means an elevation of temperature in the entering steam, it has seemed an easy step to ascribe the general improvement in economy to a corresponding direct increase in the ideal or thermodynamic efficiency of a superheated steam cycle. A moment's thought shows the error in this assumption. This formula quoted above refers to the Carnot cycle, and in which the heat given to the working substance is all communicated at the upper temperature, T_1 while in the case of superheated steam by far the larger part of the heat is communicated at the temperature of boiling, distinctly lower than the upper or superheat temperature, only a comparatively small part of the heat being communicated at the gradually increasing temperature due to the superheat condition. If, indeed, the steam could be expanded in a truly adiabatic manner and the remainder of the cycle could be carried out strictly according to the Carnot ideal, we should still fall far short of any such ideal economy as expressed in the formula $(T_1 - T_2) \div T_1$. In a typical case and in commercial terms, the conditions would be somewhat as follows: The heating of one pound of water from the lower temperature to that of boiling would mean the investment of about 230 B.t.u. at an ideal efficiency of about 14 per cent. The production of one pound of saturated steam would mean the further investment of about 860 B.t.u. at an ideal efficiency of about 28 per cent., while the superheating of this by 120° would mean the investment of some 66 B.t.u. at an ideal efficiency of some 32 per cent. The average working efficiency or earning power of this investment is seen to be, even in the ideal case, far below the 36 per cent., which would represent the value as given by the formula quoted above, where T_1 is superheat temperature. In fact, the amount of heat involved in the operation of superheat is comparatively so small that it can have, so far as pure thermodynamic principles are concerned, but slight

influence on the general efficiency of the cycle.

Actually the gain comes from an entirely different direction—in the case of reciprocating engines to which the present discussion more especially applies, from the supression in varying degree of the loss due to cylinder condensation and involving the activity of a secondary or "cast-iron" cycle, as a result of which a considerable amount of heat may be shunted past the working cycle of the engine proper, and find its way to the condenser without having taken any active part in the work-producing cycle of the engine. The general nature of these operations within the steam engine cylinder is, of course, well known to engineers, and it is by reducing the readiness of transfer between the cast-iron and the working substance that the use of superheated steam may result in an improvement in economy. The improvement is due, therefore, not to the lifting of the ideal efficiency, but rather by a closer approach to the existing ideal which is fixed by the conditions of the case in hand.

Another point brought out by our contemporary concerns the common method of reporting steam engine trials. The result of such trials are very commonly given in pounds per horse-power hour. The misleading character of this unit is too well known to need extended comment. The engine is not properly a steam engine, but rather a heat engine and the only consistent method of stating economy results must be in terms of heat expended per unit of power developed. From the very facts of the case statements of economy in terms of pounds of superheated steam per horse-power hour are entirely misleading in comparison with similar results for an engine using saturated steam, and unduly favorable to the former. Thus, in the case of two engines using in one case, say 13 lbs. of saturated steam and in the other 12.5 lbs. of superheated steam, the latter may in fact be less economical of the two engines, a relation which would be at once shown by the expression of economy in terms of thermal units rather than pounds of steam. No definite meaning can therefore be attached to the report of a test of an engine using superheated steam in which the results are stated in pounds of steam per horse-power hour, and the engineer who uses such results without transforming them into thermal units is sure to be misled at the very point which should supply him with accurate data for his guidance.

THE ENGINEERING TIMES IN NEW FORM.

The July 12th issue of the *Engineering Times,* published at 6 Bouverie street, Fleet street, London, E. C., England, comes to us in new form which, say the publishers, they have, after mature deliberation, decided is better fitted for the purpose they have always had in view. The paper in its new form is 9¾x 13¼ inches in size and is handsomely bound in heavy cover paper. It contains twenty pages of reading matter, printed on heavier paper than formerly and a special feature is a handsome supplement illustrating the inauguration of the new Argyll Works at Alexandria. We think the paper should be congratulated upon its new and improved appearance.

TRADE PUBLICATIONS.

Sargent Steam Meter Company, First National Bank Building, Chicago. Booklet describing and illustrating a new meter for measuring the quantity of steam used in an engine. This meter may be located anywhere in the steam line and will render an exact account of the quantity of steam flowing through it, irrespective of pressure. It shows at a glance the quantity of steam being used by any engine, steam pump, heating system or drying room.

The W. G. Leale Company, 119 Mission street, San Francisco, Cal.. Booklet, entitled "A New Process of Pumping," being a description of the Starrett System of pumping by compressed air as adapted to mines and other places where an economical, high duty compressed air displacement pump is applicable.

Ingersoll-Rand Company, 11 Broadway, New York. Booklet, form 73-A, giving short descriptions on various methods of pumping by means of the Air Lift System, including Pohle Method, the Central Pipe System and the Saunders System.

Sullivan Machinery Company, Railway Exchange Building, Chicago. Booklet, form 103, illustrating and describing methods of core drilling, both by power drills and hand drills. Also Booklet, form 102, devoted to coal mining by machinery and describing the Sullivan "Puncher" Pick Machine.

Chicago Pneumatic Tool Company, Fisher Building, Chicago. Special Circular No. 56, devoted to electrical tools and accessories for use in shops, shipyards, foundries, etc.

H. D. Crippen Manufacturing Company, 25 Broad street, New York. Catalogue No. 10, devoted to a comprehensive description of the Box Electric Drill for use in mines, quarries, contract work, etc. This catalogue also contains full information and net prices on the cost of installing electric drills, electric hoists, gas engines, oil engines, electric generator sets, and everything for a complete electric drill installation.

De La Vergne Machine Company, foot of East 138th street, New York. A 48-page pamphlet describing the various types of horizontal and vertical ammonia compression refrigerating machines and equipment for ice plants, breweries, packing houses, etc. Illustrated with many fine half-tones and views of plants installed in various parts of the world.

Rockwell Engineering Company, 26 Cortlandt street, New York. Eighteen-page booklet, devoted to high pressure oil burners, fuel oil pumping systems, positive pressure blowers, etc.

Whiting Foundry Equipment Company, Harvey, Ill. Catalogue No. 45, a profusely illustrated book devoted to Electric Traveling Cranes, Improved Air Hoists and other Cranes for foundries, machine shops, rolling mills, power plants and railroad service.

Hanna Engineering Works, 820 Elston avenue, Chicago, Ill. Catalogue No. 3, second edition, handsomely illustrated and devoted to Hanna Riveters, Screen Shakers, and other labor saving pneumatic tools and appliances.

Ingersoll-Rand Company, 11 Broadway, New York. Catalogue No. 383, Edition of 1906, devoted to the Temple-Ingersoll Electric-Air Rock Drill for mining, tunnelling, quarrying and general rock excavation and containing much data of both a practical and theoretical nature regarding electric wiring, engine and generator sizes, weights of wire, etc., with complete records of recent performances.

Stanley-G. I. Electric Manufacturing Company, Pittsfield, Mass. Bulletin No. 149, illustrating and describing Polyphase Induction Motors. Also Bulletins Nos. 608, 778 and 785, devoted to new G. I. Flush Pocket Wall Receptacles, Circuit Breakers, and the "K-9" Arc Lamp for multiple alternating current circuits.

Baldwin Locomotive Works, Philadelphia, Pa. Record of Recent Construction, No. 57. A handsomely illustrated description of the recent types of locomotives constructed by this company, giving full general dimensions of the engine parts.

Manning, Maxwell & Moore, Inc., 85-87-89 Liberty street, New York. A full stock list of machine tools for blacksmiths, boilermakers, builders, carpenters, foundries, machine shops, etc. These machines being kept in stock for immediate delivery.

THE cooling of air while it is being compressed, and reheating it for use in engines, are matters of great importance. If the air is cooled as it is being compressed, the volume will be much smaller, under a given pressure, than the same amount of air would occupy if allowed to retain the heat of compression. Then again, if the compressed air is heated just before it enters the engine, the volume will be increased, while the same pressure is maintained.

INDUSTRIAL.

COMPARATIVE TEST OF LARGE LOCOMOTIVE AIR PUMPS.

When Mr. George Westinghouse invented the locomotive air pump no one foresaw the degree of prominence that instrument was destined to attain in the conduct of railway transportation. That it is inseparably connected with the brake system is apparent, for without it the air brake would be useless, and without air brakes railway trains could not be operated with anything like the present degree of efficiency, to say nothing of the safety factor which the brake constantly affords. Since the advent of air brakes numerous designs of air pumps have been brought out, each answering its intended purpose, but during these years of pump development the chief efforts have been centered in designing instruments occupying little space, light in weight and of sufficient air producing capacity to supply the needs, these desiderata being looked upon as of greater importance than designs contributing to steam economy.

With the advent, however, of High Speed Brakes, long trains of air-braked cars and numerous "parasites" such as bell ringers, track sanders, water scoops, air pressure for Pullmans, and other accessories on engines and cars, all contributing through operation and leakage to exactions on the air pump, has been created a demand for pumps of great air producing capacity until a stage of steam consumption has been reached the result of which is a serious drain upon the coal pile.

It is a generally accepted belief that the Westinghouse 11-inch pump was of ample capacity to supply air for all conditions of train service, but when, a year or more ago, the New York Air Brake Company placed upon the market a duplex pump of considerably greater capacity than the 11-inch pump it was received by many railroad men with much favor, being looked upon as an instrument more capable of meeting modern requirements than any of its predecessors.

It is evident that the sentiment of those using air pumps is in the direction of abnormal air capacity, as compared to former practice, and, to those skilled in the art, that the combination of such capacity and steam economy cannot be obtained with simple

pumps. The Westinghouse Air Brake Company, therefore, has produced a pump of very superior capacity as compared to any heretofore used on locomotives and with a factor of steam economy far in excess of anything previously attempted.

The advent of this pump has created no little interest and favorable comment on the part of railway officers who, upon investigation, recognized its simplicity, capacity, and economical qualities. With a view of determining in a practical way the capabilities of this type of air compressor, a comparative test of the Westinghouse Compound and the New York No. 5 Duplex Pumps was somewhat recently made by the Lake Shore & Michigan Southern Railway Co. The schedule of tests was prepared and conducted by the engineering department of the road under the direction of the chief mechanical officers, there being present during the demonstration several prominent air brake experts of the road, as well as representatives of the two air brake companies.

To what extent the efforts of the Westinghouse Air Brake Company have proven successful is presented in the performance of their 8½" Cross Compound Pump, a record of which appears later in this article and referred to as the above company's test L 752; being a series of sketches Nos. 1596 to 1603, inclusive, and a number of diagrams plotted from the data found in these sketches. These sketches and diagrams are self-explanatory and clearly show the superiority of the Westinghouse pump, both in economy and capacity.

A very complete apparatus was employed for the tests, making entirely practical a comparison of air delivered, steam consumed, temperature of both free and compressed air as well as the general working of the pumps during the experiments; the apparatus used being arranged as shown on sketch 1603.

A locomotive boiler furnished the steam. The steam passed through a covered receiver which furnished a means for controlling the pressure and also served as a separator. The exhaust steam from the pumps was condensed in a surface condenser and weighed in the barrel arranged as shown. The delivery pipes of the pumps were connected to the constant pressure reservoir No. 3, the overflow from it being alternately measured in the measuring reservoirs Nos. 1 and 2. In arranging the pumps and reservoirs, an effort was made to have the pipe volume of each pump the same. The difference was slight, the Westinghouse pump having the larger volume. Thermometers were inserted in the delivery pipes near the discharge valves of the two pumps, and in reservoir No. 3. Pressure gauges were attached to reservoirs Nos. 1, 2 and 3, and to the steam reservoir. The strokes of the pumps were taken with an ordinary reciprocating counter. The whole apparatus was arranged so that the conditions were almost identical for both pumps, thus avoiding the necessity of making corrections for observations.

The New York No. 5 Duplex Pump has two 8" x 12" steam cylinders, and 8" and 12" x 12" air cylinders; the Westinghouse Compound has 8½" and 14½" x 12" steam cylinders and 9" and 14½" x 12" air cylinders. The New York Duplex Pump takes in free air at both air cylinders, one piston resting while the other is in motion; the Westinghouse Compound takes free air at the low pressure air cylinder only, both pistons being in motion at the same time, but moving in opposite directions.

The piston displacement of the compound for one cycle or revolution is 1.43% greater than that of the duplex.

The order in which the tests were made are given in the sketches, the figure preceding the decimal point is the day of the month and the number after the decimal point is the order of the test on that day. The tests have been divided into three classes, as follows:

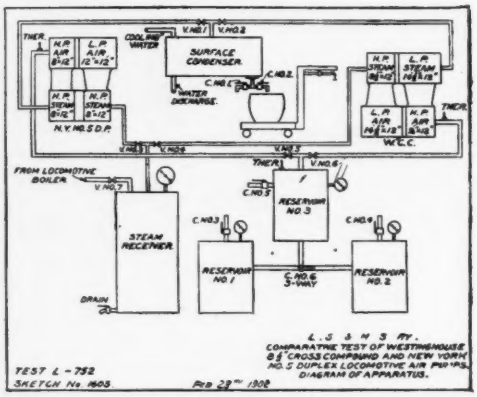
1st. Efficiency and capacity tests with pumps working against constant pressure; the results of these are shown on sketches Nos. 1596, 1597 and 1598.

2nd. Efficiency and capacity tests with the pumps working against increasing pressure as in charging reservoirs, see sketches Nos. 1599, 1600 and 1601.

3rd. Efficiency and capacity tests with the pumps working against an approximately constant pressure, an orifice in a diphragm being used to approximate the amount of air delivered; these are shown on sketch 1602, which also includes a temperature test, of 20 minutes duration.

In all these tests the pumps were working at full capacity, except in one instance, see sketch 1602, serial number of test 7.29, in which the Westinghouse Cross Compound was made to

deliver the same quantity of air as the New York No. 3 by throttling the steam; while this test was being made the steam pressure in the receiver dropped to 156 pounds. In the increasing pressure or charging reservoir tests, the logs of which are shown on sketches 1599, 1600 and 1601, the reservoirs were of slightly difference capacities, due to the difference in piping, viz: 36.3523 cu. ft. for the Westinghouse 8½" Cross Compound, and 36.3211 cu. ft. for the N. Y. No. 5 Duplex Pump. In calculating the units of comparison, time and steam per 100 cu. ft. of free air, this reservoir difference was considered, but was too small



ARRANGEMENT OF APPARATUS.

to be noticed. It will be observed that the initial pressure in these tests was 30 pounds in each case, increasing to 70, 100, 130 and 140 lbs., this minimum pressure being selected owing to the excessive pounding of the heads of the New York Duplex, a condition which largely prevailed when the pump was working against low air pressures.

In this connection it may be said that the Westinghouse Compound worked very quietly, regardless of either high or low air or steam pressures, the tendency to pound being absent even when the throttle was thrown wide open with a high boiler pressure and with little or no air pressure in the charging reservoirs. This is of special importance owing to the "racing" of pumps against low pressure being responsible for a large portion of the failures of pumps of the simple and duplex type.

The comparative diphragm tests, shown on sketch 1602, were made to illustrate the same points brought out in the comparative efficiency and capacity tests, many railroad men being more familiar with this method of comparing air pumps. These tests also serve as a check on the other results when the pumps were working under similar conditions.

As no accurate formula is known for the flow of air through an orifice, the results of this group can hardly be considered comparative. In all of these tests, except 49, the pumps were working to their maximum capacity, and although it is true that both were discharging through the same size of orifice, the higher pressure maintained by the Westinghouse pump throws additional work on it and this is not fully shown by the amount of air discharged. Test 7.29, sketch 1602, was made, however, in an effort to make the work of the Westinghouse equal to that of the New York pump in test 7.22, and to compare the steam consumption. The Westinghouse pump was, therefore, throttled so that both pumps maintained approximately the same air pressure while discharging through the same orifice, with the result that the New York pump used 110% more steam than the Westinghouse. This test also brings out the fact that to do the same work the Westinghouse pump required 126 pounds boiler pressure, whereas the New York required 200 pounds.

In the temperature tests, shown on sketch 1602, both pumps were run to their maximum capacity, the compound pumping against a 19-64" orifice, the duplex supplying a 17-64" orifice, resulting in a decidedly higher temperature for the former than would have been the case had each pump supplied the same volume of air. The results of the tests, however, have been plotted in the form of curves and are shown on one of the diagrams accompanying the sketches.

The temperature of the Westinghouse Compound Pump was much lower than that of the New York Duplex Pump for an equal interval between tests; this and the tendency of the New York pump to heat rapidly made it difficult to start it at a low temperature which could only have been done by long delays between tests. To compensate for this, the Compound was run a considerable time before starting the temperature tests in order to get its temperature equal to that of the New York pump.

It was made evident by these tests that when Mr. George Westinghouse designed and pat-

ented a compound air pump in 1873 he foresaw, even while the air brake was yet in its infancy, that at some remote period steam economy must become a ruling consideration in locomotive air pump operation, and to judge from the strenuous efforts of railways in the direction of such economy it would seem that the time has now arrived.

Serial Number of Test.....	Average of 20.1 & 20.3	Average of 20.2 & 20.4	Per cent. in favor of W. C. C.	6.3	6.4	Per cent. in favor of W. C. C.	6.5	6.6	Per cent. in favor of W. C. C.	6.7	6.8	Per cent. in favor of W. C. C.
Style of Pump	W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.	
Steam Pressure.....	200	200		200	200		200	200		200	200	
Constant Air Pressure Pumped Against.....	140	140		130	130		100	100		70	70	
Cubic Feet Free Air Pumped.	666.5	666.5		616.8	616.8		625.4	625.4		534.8	534.8	
Duration of Test—Minutes and Seconds.....	5-46.4	8-52.1		4-41.8	6-35.6		4-07.6	5-24.2		3-11	3-52.2	
Cubic Feet Pure Air Pumped per Minute.....	115.5	75.2	53.6	131.0	93.6	40.1	151.6	115.7	31.0	168.0	138.2	21.6
Cycles per Minute	61.8	53.8		65.3	58.4		74.2	66 1		81.4	72.9	
Weight of Steam Used—Pounds	143.5	317.6	121.3	121.3	249.0	105.4	116.0	207.8	79.1	94.8	164.5	74.0
Steam per 100 Cubic Feet Free Air—Pounds	21.5	47.7	121.3	19.7	40.4		18.6	33.2		17.7	30.8	
Cubic Feet Free Air per pound Steam	4.64	2.10	121.3	5.09	2.48		5.39	3.01		5.65	3.25	
Volumetric Efficiency—Per cent.....	82.1	62.2	31.9	88.2	71.4	23.6	89.7	78.0	15.0	90.7	84.5	7.3
Temperature Deg. Fahr. At Pump Discharge Initial.	313	355		280	378		330	380		320	400	
Temperature Deg. Fahr. At Pump Discharge Final..	422	480		390	500		400	497		380	470	
Temperature Deg. Fahr. In first of 3 Connected Reservoirs Initial.	154	158		161	179		190	199		200	209	
Temperature Deg. Fahr. In first of 3 Connected Reservoirs Final..	184	184		182	201		211	224		218	298	
Atmosphere.....	73	75		70	70		70	70		70	71	

L. S. & M. S. RY.
Comparative test of Westinghouse 8½"
Cross Compound and New York No. 5
Duplex Locomotive Air Pumps.
Pumps working against constant Pressure

Test L—752
Sketch No. 1596

Feb. 23, 1906

Serial Number of Test	6.15	6.16	Per cent. in favor of W. C. C.	6.17	6.18	Per cent. in favor of W. C. C.	6.19	6.20	Per cent. in favor of W. C. C.
Style of Pump	W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.	
Steam Pressure.....	150	150		150	150		150	150	
Constant Air Pressure Pumped Against ...	120	120		100	100		70	70	
Cubic Feet Free Air Pumped.	567.8	567.8		625.4	625.4		534.8	534.8	
Duration of Test—Min. and Sec	6-37.2	9-28	43.0	5-38.4	7-51.4	39.3	4-02.2	5-02.4	24.9
Cubic Feet Free Air Pumped per Min.....	85.8	60.0	43.0	110.9	79.6	39.3	132.5	106.1	24.9
Cycles per Minute	44.1	39.7		54.4	48.8		63.2	58.3	
Weight of Steam Used—Pounds	105.5	220.8	109.3	102.8	208.5	102.9	81.5	148.5	82.2
Steam per 100 cu. ft. Free Air—Pounds	18.6	38.9	109.3	16.4	33.3	102.9	15.2	27.8	82.2
Cubic Free Air per pound Steam	5.38	2.57	109.3	6.09	3.00	102.9	6.56	3.60	82.2
Volumetric Efficiency—Per cent.....	85.4	67.3	27.0	89.4	72.8	23.0	92.2	81.1	13.7
Temperature. Deg. Fahr. At Pump Discharge Initial	270	317		270	350		320	300	
Temperature. Deg. Fahr. At Pump Discharge Final..	360	440		370	450		360	400	
Temperature. Deg. Fahr. In first of three connected Reservoirs. Initial	174	175		180	182		184	186	
Temperature. Deg. Fahr. In first of three connected Reservoirs. Final..	184	185		186	190		194	196	
Temperature. Deg. Fahr. Atmosphere.....	78	78		76	78		77	77	

L S. & M. S. RY.
Comparative test of Westinghouse 8½"
Cross Compound and New York No. 5
Duplex Locomotive Air Pumps.
Pumps working against constant pressure.

Test L—752
Sketch No. 1598

Feb. 23, 1906

Serial Number of Test	7.1	7.5	Per cent. in favor of W. C. C.	7.2	7.6	Per cent. in favor of W. C. C.	7.3	7.7	Per cent. in favor of W. C. C.	7.4	7.8	Per cent. in favor of W. C. C.
Style of Pump	W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.	
Steam Pressure.....	200	200		200	200		200	200		200	200	
Initial Air Pressure	30	30		30	30		30	30		30	30	
Final Air Pressure.....	70	70		100	100		130	130		140	140	
Cubic Feet Free Air Pumped.	98.9	98.8		173.1	173.0		247.3	247.1		272.0	271.8	
Duration of Test—Minutes and Seconds.....	0–39.8	0–43.2		1–12.4	1–22.4		1–47.6	2–10.2		1–59.2	2–29.6	
Total Cycles	55	55		98	100		139	149		150	168	
Weight of Steam Used—Pounds.....	21	31.8		36.3	57.3		51.8	92		57.5	102.3	
Required to compress 100 cu. ft. Free Air { Time Sec.	40 2	43.7	8.6	41.8	47.6	13.9	43.5	52.7	21.1	43.8	55.0	25.6
From Initial to Final Pressure. { Steam Pounds.	21.2	32.1	51 4	20.9	33.1	58.1	20.9	37.2	78.0	21.1	37.6	78.0
Temperature Deg. Fahr. At Pump Discharge { Initial	208	206		242	238		269	280		310	320	
Temperature Deg. Fahr. At Pump Discharge { Final	236	252		286	304		324	370		360	410	
Temperature Deg. Fahr. In first of 3 Connected Reservoirs { Initial	100	130		106	132		122	140		134	150	
Temperature Deg. Fahr. In first of 3 Connected Reservoirs { Final.	103	138		120	140		130	156		150	168	
Atmosphere.....	69	71		70	73		70	73		70	73	

Test L-752
Sketch No. 1599

Feb. 23, 1906.

L. S. & M. S RY.
Comparative test of Westinghouse 8½"
Cross Compound and New York No. 5
Duplex Locomotive Air Pumps.
Pumps working against increasing pressure
as in charging Reservoirs.

D	17/64"	19/64"	23/64"
T	.034"	.056"	.0615"

Serial Number of Test	7.21	7.22	7.29	7.23	7.24	7.25	7.26
Style of Pump	W.C.C.	N. Y. 5 D.P.	W.C.C.	W.C.C.	N. Y. 5 D.P.	W.C.C.	N. Y. 5 D P.
Orifice in Diaphragm { Diameter—In..	17/64"	17/64"	17/64"	19/64"	19/64"	23/64"	23/64"
Orifice in Diaphragm { Area—Sq. In...	.055420	.055420	.055420	.069227	.069227	.101434	.101434
Steam Pressure.....	200	200	156	200	200	200	200
Initial Air Pressure	118	100	100	100	88	70	63
Final Air Pressure	120	102	100	104	88	73	63
Duration of Test—Min.....	2	2	.2	2	2	2	2
Cycles per Min.....	67	65.5	57.5	73.5	69.5	81.5	75.0
Steam Used per Min.—Lbs...	25.6	40.6	19.3	27.9	43.8	29.4	40.5
Temperat're Deg. Fahr. At Pump Discharge { Initial	242	310	400	300	360	301	410
Temperat're Deg. Fahr. At Pump Discharge { Final.	296	360	417	340	420	346	430
Temperat're Deg. Fahr. In Reservoir { Initial	111	126	234	140	163	170	180
Temperat're Deg. Fahr. In Reservoir { Final.	122	137	236	153	172	179	190
Temperat're Deg. Fahr. Atmosphere.....	69	72	69	73	70	72	72

Test L—752
Sketch No. 1602

Feb. 23, 1906

L. S. & M. S. RY.
Comparative test of Westinghouse 8½"
Cross Compound and New York No. 5
Duplex Locomotive Air Pumps.
Orifice and Temperature Tests.

Serial Number of Test	6.9	6.10	Per cent. in favor of W. C. C.	6.11	6.12	Per cent. in favor of W. C. C.	6.13	6.14	Per cent. in favor of W. C. C.
Style of Pump	W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.		W.C.C	N. Y. 5 D.P.	
Steam Pressure	175	175		175	175		175	175	
Constant Air Pressure Pumped Against	130	130		100	100		70	70	
Cubic Feet Free Air Pumped	616.8	616.8		625.4	625.4		534.8	534.8	
Duration of Test—Min. and Sec	5–43.2	8–32	49.2	4–43.4	6–14.2	32.1	3–31.6	4–22.2	23.9
Cubic Feet Free Air Pumped per Min	107.9	72.3	49.2	132.4	100.3	32.1	151.6	122.4	23.9
Cycles per Minute	55.1	47.1		64.8	59.2		73.4	65.9	
Weight of Steam Used—Pounds	124.5	251.0	101.6	110.8	206.3	86.2	85.8	155.5	81.4
Steam per 100 cu. ft. Free Air—Pounds	20.2	40.7	101.6	17.7	33.0	86.2	16.0	29.1	81.4
Cubic Feet Free Air per Pound Steam	4.96	2.46	101.6	5.65	3.03	86.2	6.24	3.44	81.4
Volumetric Efficiency—Per cent	86.0	68.4	25.8	89.6	75.5	18.7	90.7	82.8	9.6
Temperature. Deg. Fahr. At Pump Discharge (Initial)	320	320		298	370		300	360	
Temperature. Deg. Fahr. At Pump Discharge (Final)	400	470		384	470		368	440	
Temperature. Deg. Fahr. In first of three connected Reservoirs. (Initial)	140	168		172	185		196	194	
Temperature. Deg. Fahr. In first of three connected Reservoirs. (Final)	169	190		194	205		206	206	
Temperature. Deg. Fahr. Atmosphere	75	76		74	78		78	79	

Pumps working against constant pressure.

Serial Number of Test	7.9	7.12	Per cent. in favor of W. C. C.	7.10	7.13	Per cent. in favor of W. C. C	7.11	7.14	Per cent. in favor of W. C. C.
Style of Pump	W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.	
Steam Pressure	175	175		175	175		175	175	
Initial Air Pressure	30	30		30	30		30	30	
Final Air Pressure	70	70		100	100		130	130	
Cubic Feet Free Air Pumped	98.9	98.8		173.1	173.0		247.3	247.3	
Duration of Test—Min and Sec.	0–41.8	0–48.6		1–06.6	1–32.8		1–56	2–32	
Total Cycles	55	56		94	103		134	155	
Weight of Steam Used—Pounds	18.5	22.8		32	56		40.8	86	
Required to compress 100 cu. ft. Free Air from Initial to Final Pressure — Time—Sec.	42.3	49.2	16.4	44.3	53.7	21.4	46.9	61.5	31.1
Required to compress 100 cu. ft. Free Air from Initial to Final Pressure — Steam—Pounds	18.7	23.0	23.1	18.5	32.4	75.1	16.5	34.8	111.2
Temperature. Deg. Fahr. At Pump Discharge (Initial)	234	258		276	282		298	308	
Temperature. Deg. Fahr. At Pump Discharge (Final)	258	300		310	362		344	385	
Temperature. Deg. Fahr. In first of three connected Reservoirs (Initial)	154	163		154	160		161	162	
Temperature. Deg. Fahr. In first of three connected Reservoirs (Final)	160	168		165	199		176	174	
Temperature. Deg. Fahr. Atmosphere	74	74		73	73		75	75	

Pumps working against increasing pressure as in charging Reservoirs.

Special Number of Test	7.15	7.18	Per cent. in favor of W. C. C.	8.16	7.19	Per cent. in favor of W. C. C.	7.17	7.20	Per cent. in favor of W. C. C.
Style of Pump	W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.		W.C.C.	N. Y. 5 D.P.	
Steam Pressure	150	150		150	150		150	150	
Initial Air Pressure	30	30		30	30		30	30	
Final Air Pressure	70	70		100	100		130	130	
Cubic Feet Free Air Pumped	98.9	98.8		173.1	173.0		247.3	247.1	
Duration of Test—Min. and Sec.	0–46	0–55		1–26.4	1–47		2–21	3–08	
Total Cycles	52	57		95	98		137	154	
Weight of Steam Used—Pounds	15	29		29.5	52.8		44	85.3	
Required to compress 100 cu. ft. Free Air from Initial to Final Pressure — Time—Sec.	46.5	55.6	19.7	49.9	61.9	24.0	57.0	76.1	33.4
Required to compress 100 cu. ft. Free Air from Initial to Final Pressure — Steam—Pounds	15.2	29.3	93.5	17.0	30.5	79.0	17.8	34.5	93.9
Temperature. Deg. Fahr. At Pump Discharge (Initial)	240	240		255	275		302	350	
Temperature. Deg. Fahr. At Pump Discharge (Final)	264	280		293	330		344	400	
Temperature. Deg. Fahr. In first of three conected Reservoirs (Initial)	165	162		160	162		159	174	
Temperature. Deg. Fahr. In first of three conected Reservoirs (Final)	170	168		172	170		175	190	
Temperature. Deg. Fahr. Atmosphere	76	78		75	78		77	78	

Pumps working against increasing pressure as in charging Reservoirs.

THE Traylor Engineering Co., and the Traylor Manufacturing and Construction Co., have been consolidated into one corporation, under the name of the Traylor Engineering Company.

The consolidation was the result of the rapid increase of the business of the Traylor Engineering Co., which made it desirable to combine the two concerns in order to simplify and expedite the conduct of their business. Under the old arrangement the Traylor Engineering Company was the active concern dealing with the public, while the Traylor Manufacturing and Construction Company owned the works at Allentown, Pa., and did the manufacruing under contract for the other. Both concerns belonged to the same stockholders. They were organized under the laws of New Jersey. The new corporation is organized under the laws of New York. It takes over all the assets and business of the older corporations and assumes their liabilities. The two New Jersey corporations have been dissolved. The change in incorporation makes no change in the business to simplify its internal conduct. The public will continue to find the Traylor Engineering Co., at its offices in the Engineering Building, 118 Liberty street, New York, and with its constantly increasing staff of experts always ready to give advice on Mining, Metallurgical, Cement-making, Fuel Briquetting or Rock Crushing matters.

The Officers of the corporation are: President and Treasurer, Samuel W. Traylor; Vice-president, Bruce W. Traylor; Assistant Treasurer, Frank W. Hopkins; Secretary, Joseph S. Buhler.

The capital stock authorized is $600,000. Of this amount $500,000 is issued to pay for the properties and business taken over, and the balance remains in the treasury for future needs.

A NEW plant will shortly be constructed at Plainfield, N. J., for the Vacuum Cleaner Company, 427 Fifth Avenue, New York. The company proposes to manufacture its wagons, vacuum pumps and other carpet and rug cleaning machinery. Dodge & Morrison, of 82 Wall street, are the architects of the proposed plant and they will also have charge of the engineering details. The plant will consist of a main factory building of mill construction, 60x170 feet, two stories in height. The main building will contain a machine shop, general assembly department, paint and wood-working department, etc. There will be a brass foundry, 20 x 50 feet; power house, 42 x 42 feet; pattern building 15 x 20 feet, and pattern storage building, 15 x 20 feet. The machinery details have not been worked out as yet, with the exception that it has been decided to install about 200 horse-power of boilers and most of the machinery equipment of the plant will be electrically operated. Besides purchasing a complete brass foundry equipment the company will require a rather general assortment of machine tools and some woodworking equipment. These details are all in the hands of Dodge & Morrison, who will also let the contract for the construction of the building. It is proposed to give out that work very shortly and the plant will be built as soon as possible. The company has a desirable location adjacent to the tracks of the Central Railroad of New Jersey and arrangements will be made to construct a spur from the main line into the company's property and through the erecting yard, in which will be built an erecting platform, in order to facilitate the shipping of the firm's product. The company has purchased considerable property to allow for enlarging its plant when there is necessity for it.

A HUGE UNDERTAKING SUCCESSFULLY COMPLETED.

The great new Government Custom House opposite the historic Bowling Green has just received its final treatment at the hands of the American Diamond Blast Co.

Five months of labor resulted in a beautiful looking building. The stone of which it was built was carefully tooled and finished, but to bring out its true color the company's sand blast treatment was used with wonderful effect. Three hundred and sixty thousand square feet were thoroughly worked over, much time being devoted to the ornate carvings, which required the most careful manipulation.

Other buildings in the neighborhood which have been restored to their original purity of exterior are the Empire Building, Banking House of J. P. Morgan & Co., and the County Court House.

A new corporation, known as the Pittsburgh Pneumatic Company, with a capital of $250,000 has been formed with Pittsburgh men behind it and will shortly build and operate a large plant for the manufacture of pneumatic tools. It is considered that the establishment of this new industry in Pittsburgh is of unusual interest, because up to the present time there are no plants making pneumatic machines in the form of riveters and drills in the Pittsburgh district, though there are few markets of greater importance for these machines than this section.

The new company has elected officers, with Frank M. Faber, president; Charles H. John-

son, treasurer, and Charles C. Murray, secretary. The officers are practical pneumatic tool men. When the plant is in running order it will give employment to a large number of skilled mechanics.

A NEW COMPRESSED AIR COMPUTER.

William Cox, 75 Broad street, New York, has recently devised a very useful addition to the list of computers which he manufactures. The accompanying illustration shows the general style of Mr. Cox's computers, which now number over a hundred, each being designed to solve some special formula relating to the flow of air, gas and water. His latest computer, however, is designed to solve the formula

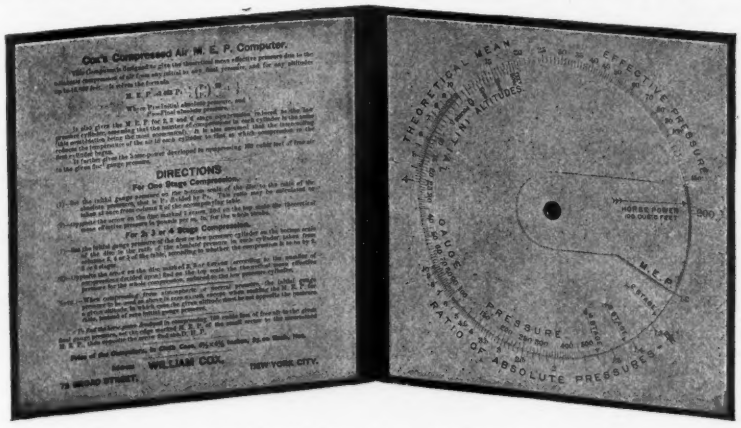
$$\text{M. E. P.} = 3.463\ P_1 \left[\left(\frac{P_2}{P_1} \right)^{.29} - 1 \right]$$

in which P_1 = the initial absolute pressure; P_2 = final absolute pressure. This being the formula for the theoretical mean effective pressure in single-stage compression.

Accompanying the instrument is a table of ratios of compression from atmosphere to 2,000 lbs., the table giving the ratios for single-stage compression and the ratio for each cylinder for 2, 3 and 4-stage compression.

The mean effective pressure once found, the horse-power required to compress 100 cu. ft. of free air is determined by setting the M. E. P. edge of the sector to the ascertained mean pressure when; against the horse-power arrow, will be found the horse-power required.

Among the latest additions to Mr. Cox's list of computers might be mentioned computers for solving the horse-power transmitted by belts, computers for paper friction pulleys, and for testing electrical meters.


Cox's Compressed Air M. E. P. Computer.
DIRECTIONS
For One Stage Compression.
For 2, 3 or 4 Stage Compression.
WILLIAM COX,
75 BROAD STREET, NEW YORK CITY.
THEORETICAL MEAN EFFECTIVE PRESSURE
HORSE POWER REQUIRED PER 100 CUBIC FEET
M. E. P.
RATIO OF ABSOLUTE PRESSURES

COX COMPRESSED AIR COMPUTERS.

A SPECIAL caisson has been sunk at the foot of Fifteenth street, Jersey City, in the construction of a connection between the Hudson Company's tunnels from Morton street, New York, under the North River to Jersey City, with branches to the terminals of the Erie and of the Dalaware, Lackawanna & Western Railroads. This caisson is near the working shaft for the main tunnels, and was sunk to facilitate the building of the divergent tunnels at their point of intersection. The single-track tubes of the connections are located to clear each other vertically and as the tunnel structure at this point could not be readily built by ordinary tunneling methods, special provision has been made for it by the use of a pneumatic caisson sunk 80 ft. or more through earth and water into the rock. The caisson, which is five-sided and is opproximately 100 ft. long and half as wide, is constructed of reinforced concrete, affording a large estimated economy over the use of steel or timber. It consists of a massive concrete block containing a working chamber and an upper chamber separate from the latter. The working chamber eventually forms one section of the low-level tunnel; the upper chamber forms the corresponding section of the upper-level tunnel. The lower chamber was provided with an air-tight lining cemented in position to prevent the leakage of air pressure through the porous concrete.

PRACTICAL ITEMS for PRACTICAL MEN.

To the Editor of COMPRESSED AIR:

Dear Sir.—I, believing you are in search of information in relation to the practical side of compressed air, will in the following few lines try to give some of my experiences in repairing pneumatic stone tools.

If the instructions given by every manufacturer of stone carving tools were followed closely, their repair bills would be a great deal less. Sometimes in my experience we have had to cut away the outer casing on carving tools just because the user has neglected to soak the tool in coal oil over night and has used instead of a pneumatic oil any oil which was handy. The ports become clogged up and no amount of soaking will dislodge the grit from these ports. This clogging does not take place immediately, but goes on gradually and, you might say, is not noticeable until perhaps a new tool is started, then the other is noticed not to be working up to standard. The redress is the repair shop. Now, again, this neglect to clean the tool will cause fine particles of foreign matter in the air to collect in the ports, these particles being so fine that, were the tools clean, they would go through without lodging; but when collected together they are dangerous, especially when the user realizes that he has been starving the tool and then gives it a large dose of lubricating oil without taking it apart and cleaning it. This is the time that these small particles of grit get in their work, causing the tool to wear loose sooner than it should. This is only one small word of advice to the users of pneumatic tools, but if followed up they will find that this neglect is costing them more than they think.

JOHN GRACE.

HEATING RAILROAD SWITCHES.

The Scientific American directs attention to a new method of heating railroad switches. The greatest difficulty that railroads have to contend with in winter time is the blocking of switches with snow and ice. When the snow is wet and freezes, the difficulty increases. To overcome these serious conditions attempts have been made to heat the switches with electricity, but that has proved expensive and dangerous. Steam-heated switches have also met with but little success, due to the danger of condensation and subsequent freezing, which would entirely block the steam pipes. A new system has been developed in which oil is used in place of steam—hot oil of a special quality circulated through pipes placed between the ties. The advantage of oil over steam is that it retains the heat better, and will not chill to 25 degrees below zero. Furthermore, if it should chill, it will not expand and burst the pipes as water would when freezing. A test of the system on the Boston and Main Railroad is said to have been very satisfactory.

REVERSIBLE STEAM TURBINE.

A recent issue of the *Mechanical Engineer* gives a description of a reversible steam turbine, in which the reversal is effected by two sets of vanes set on concentric circles with reference to the rotating shaft, one set of veins being so constructed as to move the shaft forward and the other so as to move it in the reverse direction. Leakage of steam from the various passages is prevented by means of light steel stampings used to cover annular openings in the stationary element into which it is admitted and, by its escaping through the narrow openings under the steel stampings, has its velocity so increased that leakage of live steam in the reverse direction is prevented.

SUPERHEATED STEAM.

The following statements regarding the use of superheated steam can be readily derived from the principles of its action:

First, superheated steam is more effective in saving with simple than with compound or multiple-stage engines, or conversely.

Second, with superheated steam there is less need for multiple-stage engines beyond the compound.

Third, superheated steam, in order to realize its full possibilities, should be carried in superheat to a point which will insure a superheated vapor throughout the admission and expansion stages of the cycle. With high-expansion ratios this will be difficult to realize completely, but the more nearly this condition is fulfilled the more effective the action in reducing the loss by cylinder condensation.

Fourth, superheating carried beyond this point will be of little additional value and will scarcely justify the additional expense.

Fifth, superheating should be carried to a higher degree as the expansion ratio is higher, and therefore to a higher degree for compound and multiple-stage engines than for a simple engine.

Sixth, a moderate degree of superheat is of comparatively small value, for the reason that the steam is quickly reduced by the operation of expansion, or even before, to the saturated or moist condition, with the resulting increase

in the loss by the activity of the secondary or "cast-iron" cycle. While there is no sharp line, and while some gain will be derived from low degrees of superheat, such gains will hardly begin to be significant until a superheat of some 40° or 50° is realized, and from such point upward the gain will be continuous for further superheat until the approach of the limit mentioned under the third conclusion.

Seventh, superheating may be carried out in stages between the operations of expansion, as in the receiver of a compound engine, and in such case the sum of the partial superheats may be made less than when the entire operation is carried out at once, as in the usual arrangement.—*Engineering Record.*

COST OF POOR LUBRICATION.

The Southern Engineer in a very excellent article on "Cylinder Lubrication" mentions a certain engine builder who was an advocate of the practice of using no oil on the valves and cylinders of engines. He installed an engine in a neighboring plant, taking care that no oil or grease be used in tapping or boring, claiming that if there was never any oil or grease used in the pores of the iron, the condensation of steam would adher to the metal. Consequently no holes were drilled in the steam pipe of the engine whereby oil could be introduced. The engine was in use for a number of years, and during this time the cylinder head was removed frequently for examination. At no time could any perceptible wear be detected by the use of calipers and straight edge, either in the valve or the cylinder.

This test should convince any fair-minded person that it is not absolutely necessary to use a lubricant in a properly constructed engine. To offset this very desirable showing is the fact that it was shown from indicator cards that the coal consumption was enormous. After several years run under the above conditions a lubricator was attached to the engine. Since then it has shown a saving of 1-3 pounds of coal per horse power per hour.

Crude oil, according to the results of recent experiments, has a fuel value per pound equal to that of 2,785 pounds of California coal. The oil weighs 7.6 pounds per gallon, so that 94½ gallons equal a ton of the coal specified.

CHIPPINGS.

WHAT HOT AIR COSTS BELGIUM

A Belgian statistician has just made the discovery that the sittings of the Belgian Parliament cost the nation $1,457 an hour, or more than $24.00 a minute. He deduces that most of this money is lost to the nation because of useless loss of time expended in the making of the laws, long speeches which never carry conviction into the enemy's camp, interruptions and applause.

A centrifugal pump, to operate at a high efficiency, is necessarily limited to special purposes. With refined machines, 80 per cent. of useful effect is attainable, but one that will utilize 60 per cent. of the power applied is likely to be the best machine to buy. The efficiency attainable in various uses is from 40 to 80 per cent. being lowest in dredging machines, but the strange feature of the matter is the constant inquiry respecting efficiency. A customer will go to a maker or dealer in displacement pumps and purchase one to operate at an efficiency of 25 to 35 per cent. and never make an inquiry or ask a guaranty of effect.

HAPPY MEXICO.

The most remarkable mountain of iron in the world is in the State of Durango, Mexico; it is 4,800 feet long by 1,100 feet wide and 640 feet high. Engineers estimate that it contains between 500,000,000 and 600,000,000 tons of ore above the surface, and it is known that the deposit extends under ground for a radius of three or four miles in all directions. The ore is high grade, containing roughly 70 per cent. iron and only about 0.03 per cent. phosphorus. People who dig wells or sink shafts for any purpose in the vicinity of Durango strike iron, and there is a theory that 75 to 100 feet below the surface is a solid stratum of iron covering an area as big as a county. There is enough iron in sight to last the entire world for a century.

SUBWAY COOLING PLANTS.

An experimental plant for cooling the air in the Brooklyn Bridge station of the New York Subway is under construction. It is expected that it will be in operation before the end of August, and, if it is successful, similar plants will be built at other stations. The principle of the plants, there being two of them—one on the uptown and one on the downtown side

—is that of cooling air by passing it over cool water forced through large coils. There are fans to draw the fresh air in from the street, and also to force it into the station after it has been cooled. The water used in cooling the air is obtained from four driven wells, two at the northern end of each platform. There is a pump capable of drawing 450 gallons of water a minute connected with each pair of wells. The water, which comes out at a temperature of from 52 to 62 degrees Fahr., is conducted to two large coils of pipes, over which the air passes. Each coil has a surface sufficient to cool 75,000 cubic feet of air a minute. From the coolers the air will be distributed to the station through large galvanized iron ducts running over the four platforms. It is estimated that the temperature in stations will be lowered at least fifteen degrees. Several other cooling experiments will be tried this summer, and by another season it is hoped to have all the stations equipped with the device that proves the most successful. Work is also going on now in making the openings between the stations, in which automatic valves are to be installed.

In discussing the widening use of compressed air in shop and foundry, Professor J. J. Flather, in "Cassier's Magazine" says:

"In most cases no attempt has been made to use the air efficiently; its great convenience and the economy produced by its displacement of hand labor have until recently been accepted as sufficient, and greater economies have not been sought.

"In the matter of compression we still occasionally find very inefficient pumps in use, but manufacturers generally have learned that it pays to use high grade, economical compressors. The greatest loss is that in the air motor itself. In a large number of cases it is impracticable, or, at most, inconvenient to employ re-heaters, and we find very generally that the air is used at normal temperature for the various purposes to which it is applied.

"To obtain the most satisfactory results, the air must be used expansively; but usually where the demand for power is intermittent, no attempt has been made to reheat the air, and as a result the combined efficiency of compressor and motor is quite low, varying in general from 20 to 50 per cent. While low working pressures are more efficient than high, the use of such pressures would demand larger and heavier motors and other apparatus which is undesirable. The advantages of higher pressures in reducing cost of transmission are also well recognized, and the present tendency is to use air at 100 to 150 pounds instead of the 60 or 70 pounds of a few years ago.

"By reheating the air to a temperature of about 300 degrees F., which may often be accomplished at small expense, the efficiency is greatly increased; in some cases the increase has been found to be as high as 80 per cent. While the lower pressures are yet more efficient, the loss due to higher compression is not serious.

"If air be used without expansion, there is a material loss in efficiency; but, on the other hand, if it be used expansively without reheating, trouble may be experienced from drop in temperature below the freezing point. With moisture present, this drop will cause the formation of ice, which may clog the passages if proper precautions are not taken to prevent it. The low temperature will not in itself cause trouble; if, therefore, the moisture which the compressed air holds in suspension be allowed to settle in a receiving tank, placed near the motor or other air apparatus, and frequently drained, trouble from this cause will be largely avoided.

"While it may be impracticable to reheat the air in certain cases, yet there are many situations where a study of means to overcome the losses referred to would result in marked economies."

A PNEUMATIC TIDAL GAUGE.

Owing to the fact that no fewer than 522 dangerous rocks and shoals, twenty-six of which "were discovered by vessels striking on them," were reported to the British Admiralty in 1905, the Admiralty has been experimenting with an instrument calculated to be of much service in localities where a shelving and shifting beach necessitates a tide pole or tide watchers.

The instrument is called the manometer. This is described as a pneumatic tide gauge, fitted with a reservoir of compressed air, the pressure due to the height of the tide being balanced by the recorded pressure of a continuous current of air passing through the apparatus and slowly escaping through rubber tubing at a fixed point under water.

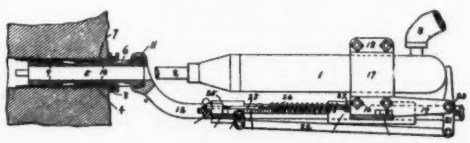
The Admiralty report on the subject states: "It is a remarkable fact that the number of rocks and shoals discovered each year steadily increases; while such continues to be the case the need is obvious for more numerous and more detailed hydrographic surveys."

823,281. TRAIN-STOPPING APPARATUS. JOHN H. KING, Cincinnati, Ohio. Filed April 8, 1905. Serial No. 254,473.

823,315. AIR-SUPPLY APPARATUS FOR AIR-BRAKES. ERNEST B. ALLEN, Louisville, Ky. Filed Feb. 13, 1906. Serial No. 300,852.

Claim.—An air-supply apparatus for air-brakes, comprising a main reservoir for compressed air, a single-acting pump mounted on the truck and having at one end a suction-valve opening inwardly from the atmosphere and an outlet-valve with pipe leading therefrom to the reservoir, a cam fixed to the car-axle, a piston in the pump-cylinder with rod and shoe having a range of adjustment to or from the cam, a slide-rod arranged beside and outside the pump-cylinder and having an arm connected to the piston-rod and shoes and means for adjusting said slide-rod and shoe to contact with the actuating-cam substantially as described.

824,250. PNEUMATIC-TOOL HOLDER. AMBROSE E. KNAPP, Seattle, Wash. Filed Nov. 27, 1905. Serial No. 289,232.



Claim.—In a tool-holder, the combination of a sleeve having a square hole and dovetail slots longitudianlly-extending engaging members mounted in said slots and provided with teeth on their outer sides and a plurality of inclines on their inner sides, said sleeves having inclines corresponding thereto, a spring-ring adapted to hold said engaging means in position, a tool-holder comprising parallel rods secured to one end of said sleeve, and a tool-carrier slidably mounted on said rods.

824,351. STONE-QUARRYING MACHINE. EMERSON T. MORRIS, Derwent, Ohio, assignor of one-half to George H. Morris, Derwent, Ohio. Filed March 8, 1905. Serial No. 249,120.

Claim.—In a stone-quarrying machine, the combination of a stationary structure, a main framework supported thereby, means for imparting a rectilinear reciprocating movement thereto, a cutter mounted upon said framework, means for reciprocating the cutter at a right angle to the plane of movement of the main framework, a second framework, operating mechanism carried by said second framework, a feed mechanism, connecting means between said operating mechanism and said cutter and freed mechanism, a crank connection between said second framework and the stationary structure and slidable with reference to the latter, whereby provision is had for proper feed of the cutter, and a telescoping guide connection between the main framework and said stationary structure.

824,585. PNEUMATIC GRAIN-MOVING APPARATUS. JULIUS C. REITH and JOHN H. CHAMBERLAIN, Chicago, Ill. Filed June 5, 1905. Serial No. 263,767.

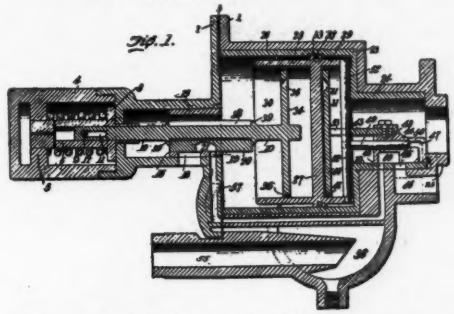
824,681. PRESSURE-REGULATOR. FRANK M. ASHLEY, Brooklyn, N. Y., assignor of one-half to Albert T. Scharps, New York, N. Y. Filed Feb. 19, 1902. Serial No. 94,727.

824,683. PNEUMATIC CARPET-CLEANER. JOHN L. CHESNUTT, Chicago, Ill., assignor to Thomas G. Orwig, Des Moines, Iowa. Filed Jan. 2, 1903. ,Renewed Nov. 29, 1905. Serial No. 289,666.

Claim.—In a pneumatic carpet-cleaner, an open-bottomed case having vertical grooves in the inside faces of its ends and an air-distributer having fixed journals on its ends adapted to traverse said grooves to change the inclination of the air-distributer, combined to operate as set forth for the purposes stated.

824,604. PNEUMATIC TIRE. CHARLES R. TWITCHELL, Los Angeles, Cal., assignor of one-half to James M. Brennan, Los Angeles, Cal. Filed Sept. 25, 1905. Serial No. 280,029.

824,712. AIR-BRAKE MECHANISM. JOHN DILLANDER, San Francisco, Cal. Filed July 6, 1904. Serial No. 215,482.

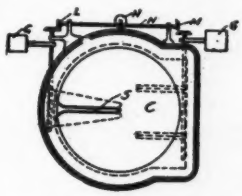


Claim.—In air-brake mechanism, a main valve, a graduating-valve, and independent pistons for moving said valves successively on a graduated application, and simultaneously through the entire stroke on an emergency application.

824,718. FLUID-PRESSURE BRAKE. JAMES A. HICKS and FRANK H. HILL, Atlanta, Ga. Filed July 27, 1905. Serial No. 271,491.

Claim.—In a fluid-pressure brake system, means for directing air from the main brake-pipe directly into the brake-cylinder independently of the triple valve, and automatic means controlled by auxiliary pressurue for establishing and cutting off the flow of air from the brake-pipe to the brake-cylinder.

824,876. AIR-LOCK FOR CAISSONS. SAMUEL MATTSON, New York, and WILLIAM M. TORRANCE, Yonkers, N. Y. Filed Oct. 27, 1905. Serial No. 284,609.



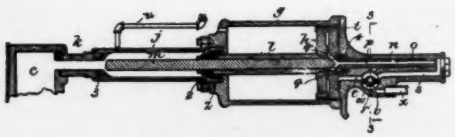
Claim.—In an air-lock the combination with one of the openings thereto, of a main door constructed to close entirely across the opening and provided with a rope-passing slot extending from one edge to the middle part of the door with respect to the opening, and a slot-closing door hinged from the side of the lock opposite the side from which the main door is hinged, and constructed to close the slot when the main door is closed.

825,077. FLUID-PRESSURE BRAKE. WILLIAM H. SAUVAGE, New York, N. Y., assignor to Sauvage Safety Brake Company, a Corporation of New Jersey. Filed Dec. 26, 1905. Serial No. 293,160.

825,113. SUPPORT FOR COAL-DRILLS. WILLIAM H. CLARKSON, Edwards Station, Ill., assignor to Eluide J. Clarkson, Edwards Station, Ill. Filed Jan. 30, 1905. Serial No. 243,299.

825,160. PROCESS OF AND APPARATUS FOR BLOWING HOLLOW GLASS ARTICLES. PAUL T. SIEVERT, Dresden, Germany. Filed Jan. 7, 1905. Serial No. 240,003.

825,164. ELASTIC-FLUID TURBINE. EDWIN F. TAYLOR, Wyncote, Pa. Filed Oct. 29, 1904. Serial No. 230,536.

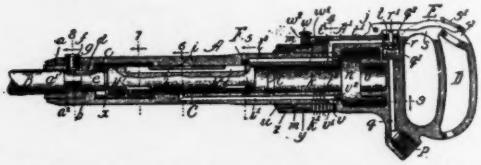


825,301. HYDROPNEUMATIC PRESS. EDWIN D. CODDINGTON, North Milwaukee, Wis. Filed Aug. 5, 1903. Serial No. 168,250.

Claim.—In a hydropneumatic press the combination with a ram and a cylinder therefor, of a cylinder provided with two independently-movable pistons, and with a tubular extension having larger and smaller bores, and plungers attached to said pistons and fitted one within the other to work in the smaller and larger bores respectively of said cylinder extension, substantially as described.

825,592. DEVICE FOR INFLATING PNEUMATIC TIRES. ALFRED T. FISHER, Brooklyn, N. Y. Filed Dec. 5, 1904. Renewed June 14, 1906. Serial No. 321,668.

825,669. PNEUMATIC TOOL. HERMAN LEINEWEBER, South Chicago, Ill., assignor to International Tool Company of Chicago, a Corporation of Illinois. Filed March 20, 1905. Serial No. 251,048.



Claim.—In a pneumatic tool, the combination with the casing containing a reciprocating piston and air-chambers at opposite ends thereof, to which the actuating air-pressure is fed through the piston, and from which said pressure is exhausted, of an impact-shoulder in the forward chamber, a bushing seating against said shoulder, a tool inserted at its stem into the casing through said bushing and shoulder, said stem containing a longitudinal groove, a tubular nut screwed through the casing into said bushing, and a spring-pressed stud confined in said nut and working through the casing and bushing to engage said groove, for the purpose set forth.

825,719. HYDRAULIC AIR-COMPRESSOR. MAX F. GUTERMUTH, Darmstadt, Germany. Filed April 29, 1902. Serial No. 105,137.

Claim.—A hydraulic compressor comprises a series of suction-pipes provided with air-inlets, and a compression-pipe having at its upper end a series of tubes or channels each connected with one of the suction-pipes, the said tubes or channels converging downwardly, while the lower portion of the compression-pipe is constituted by a single comparatively wide pipe.

825,786. AIR-BRAKE GOVERNOR. LEONARD F. WILLIAMS, Thurber, Texas. Filed Aug. 26, 1903. Serial No. 170,849.

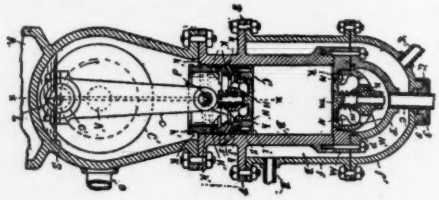
825,935. MACHINE FOR DELIVERING LIQUIDS. PHILIP POVLOTZKY, Chicago, Ill. Filed Sept. 6, 1905. Serial No. 277,243.

Claim.—In a machine for delivering liquids, the combination with a valve-controlled supply-pipe, and a delivery-pipe having means to supply air-pressure thereto, of a cup adapted to carry liquid and movable from the supply-pipe to the delivery-pipe.

825,950. STEAM-ENGINE AIR-PUMP. WILLIAM WEIR, Cathcart, Scotland. Filed Sept. 28, 1905. Serial No. 280,492.

825,961. PNEUMATIC HAIR-COLLECTOR. JAMES W. DECKERT, Oakville, Canada. Filed Oct. 4, 1905. Serial No. 281,260.

825,973. COMPRESSOR FOR ICE-MACHINES. CASPER W. MILES, Cincinnati, Ohio. Filed May 1, 1905. Serial No. 258,198.

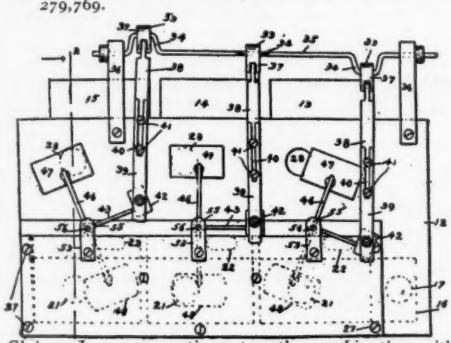


Claim.—In an ice-machine compressor having a jacketed vertical cylinder, and an inlet-valve in the plunger so that the cool gas enters through the plunger and escapes at the upper end of the cylinder, an oil-receptacle on the interior face of the plunger, an annular oil-receptacle at the lower end of the outer face of the plunger, said interior oil-receptacle being at greater elevation than the exterior oil-receptacle, and a passage through the plunger-wall connecting said oil-receptacle.

825,990. FLUID-PRESSURE BRAKE. WALTER V. TURNER and DAVID M. LEWIS, Raton, New Mex., assignors to The Westinghouse Air Brake Company, Pittsburg, Pa., a Corporation of Pennsylvania. Filed Aug. 29, 1902. Renewed Nov. 5. 1904. Serial No. 231,542.

Claim.—In a fluid-pressure brake, the combination with a train-pipe and brake-cylinder of a valve for controlling the brake-cylinder-exhaust port, a movable abutment operated by an increase in train-pipe pressure for moving said valve to restrict said port and yielding means for returning said valve to open said port.

825,997. PNEUMATIC MOTOR. PEDER WIGGEN, Chicago, Ill. Filed Sept. 23, 1905. Serial No. 279,769.

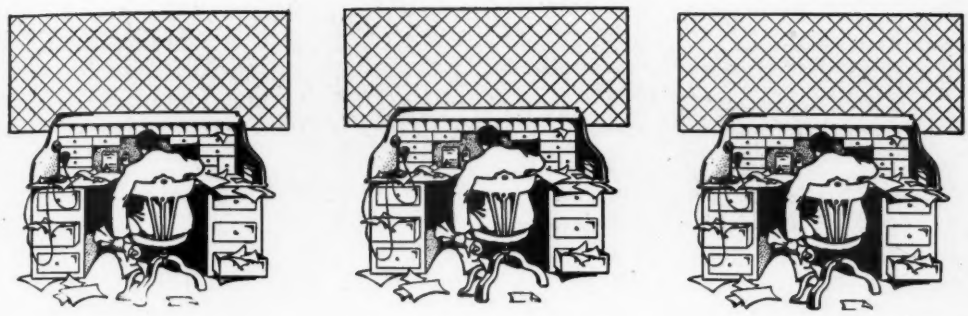


Claim.—In a pneumatic motor, the combination with a main casing or supporting-frame having an exhaust-conduit and provided with inlet and exhaust ports, of a chambered casing inclosing the exhaust-ports, a series of pneumatics on the casing and having communication with the inlet-ports and exhaust-conduit, a crank-shaft journaled on the main frame, connections uniting the pneumatics to the cranks of said shaft, a series of rock-shafts journaled on the frame, an arm mounted on each of said shafts and extending in opposite directions therefrom, a valve on one end of each of said arms to open and close the inlet-ports and a valve on the other end of each of said arms to open and close the exhaust-ports, and connections uniting the rock-shaft and cranks of the crank-shaft, substantially as described.

826,018. HOSE-COUPLING. ISAAC R. CONCOFF, Portland, Ore. Filed Nov. 21, 1904. Serial No. 233,770.

826,064. PUMP. JOHN J. REILLY, Louisville, Ky. Filed June 19, 1905. Serial No. 265,902.

Claim.—An air-displacement pump embodying a cylinder, a hollow inclosed supporting-base therefor divided into separate water-inlet and water-delivery compartments which communicate with the cylinder through the top of the base, intake and outlet valves located in the cylinder-bottom and controlling such communication, an air-valve for said cylinder, and valve-operating connections between said valve and a float within the cylinder.



Office
CHIT-CHAT

IT has been said that what is sauce for the goose is sauce for the gander, or, as a later day genius remarked, what is sauce for the goose is saucy for the gosling.

¶ In the interest of COMPRESSED AIR and for the purpose of securing paid subscriptions from a number of people who for one reason or another had been receiving the paper free for various periods, we composed at the expense of considerable grey matter a letter, several hundred copies of which we mailed to our erstwhile "subscribers."

¶ Having sent out this sauce, it is only fair to those who received our hint to reprint some of the sauciness which was handed back to us by return mail.

¶ The letter which we sent out read as follows:

GENTLEMEN:

Sherman said, "War is hell!" We could say the same about building up a good list of subscribers. You have never answered our letter which we sent you when we took hold of "Compressed Air," and we were forced to conclude that you did not think the paper worth anything *unless you got it for nothing*. Much as we should like to scatter our words of wisdom to the four corners of the earth free of charge to everybody, the United States Postal Laws do not permit of our doing this except at an expense which makes our philanthropy look sick.

We have a list of over a thousand people who used to get "Compressed Air" for nothing, and out of that thousand there were ten who responded to our letter and sent us $1.00 apiece when we told them that we could not go on giving our paper away. The other nine hundred and ninety handed us a green lemon, by ignoring our communication and intimating by a vast and deep silence that all the numbers of "Compressed Air" which they HAD received were not worth a paid subscription of $1.00 which we requested in order to *help* put the magazine on its feet.

We are willing to let bygones be bygones but we don't want our old readers to be hasbeens and we are more than willing to meet you three-quarters of the way. Send us your order and we will enter your subscription until JANUARY, 1908, sending you the paper for the remainder of this year. If this does not appeal to you, and if we do not hear from you, we are liable to insist more strongly upon your subscribing even if we have to send each new subscriber a check for $100. Don't put yourself in the position of being under obligations to us, but send us a dollar and get a full dollar's worth of paper, ink and brains in return.

Awaiting your reply with feverish expectancy, we are,

Yours very truly,

¶ At first blush it might seem that a letter such as the above is decidedly too light and airy a method of soliciting subscriptions, but we resolved to take the chance as our former letters, written in a sober and dignified vein, seemed to fall on barren ground.

¶ Imagine the shock on opening the first reply and finding the following:

GENTLEMEN:

Your letter of August 3rd just received. We must confess that it is the worst specimen of an advertising, or business getting letter that we have ever had occasion to read. A more insulting or cheap affair could not be

written. If you will take the trouble to glance on your books, you will see that we have a paid up subscription to "Compressed Air" to January 9, 1907. If we subscribe again, it will be because your paper shows extraordinary merits during the remainder of this year, and not because of brilliant, slurring letters like the one just received.

A beginner in an advertising course of instruction would know enough not to use slang in a letter.

Very truly yours,

¶ The second letter which follows caused our editorial hearts to beat faster still.

GENTLEMEN:

I presume that you claim to be gentlemen, and therefore address you as such, but if one may judge from the tone of the communication on the other side there is a big mistake somewhere.

I have received several copies of "Compressed Air" it is true, but I have no recollection of ever having asked you to send it. Of course, if you want to send out copies of your paper you are at liberty to do so, but it is a distinct insult to send such a letter after them. It is also a big business mistake.

You neither gain subscribers nor friends by such methods.

I note that you are awaiting my reply with "feverish expectancy." Well, you have it.

But I think you have another fever coming before the "long expected" dollar arrives.

Yours very respectfully,

¶ When the third letter was opened we experienced a sensation similar to that which one encounters after being thrown into a bathtub full of ice water.

GENTLEMEN:

Some years ago I was asked by the publishers to accept a free subscription to "Compressed Air." I did not want it and declined. The paper came, and twice I requested its discontinuance, but my request was unheeded.

This circular letter is an insult, uncalled for and injudicious. It will make 990 minus rather than possible clients. If I really wanted your publication the receipt of such a concoction of abusive slang would be sufficient to induce me to look elsewhere for any information or instruciion in the line of pneumatics.

Yours truly,

¶ There were some more like the above, but our modesty forbids our reprinting them.

¶ The next thirty odd letters opened were as amusing as they were gratifying and lucrative. For fifteen or twenty minutes it rained dollar bills, checks and money orders, but better, far better than the actual currency thrust upon us were the re-assuring sentiments and bantering words which clearly said, "lets be friends." A few of these letters read as follows:

GENTLEMEN:

Yes; "War is hell," likewise are many other affairs in this life, one of which is the parting with your hard earned, sweat covered $$$ without getting v. r. therefor.

To get v. r, is Heavenly, therefore to get ten times v. r. is ten times Heavenly, and here goes One "Simoleon" on the 10 Act, viz.: Compressed Air to January 1st.

Information gained from your last issue worth more than ten times the annual subscription.

With best wishes for your success, I beg to remain,

Yours very truly,

GENTLEMEN:

There is a question in my mind whether the quotation "War is Hell" referred to in your letter is warmer than the letter itself. I do congratulate you upon your able presentation of your situation, and in appreciation of same I enclose herewith my check for $1.00, for which you will please enter my subscription for one year. I am sending this by return mail in order that you will not overwhelm me with a check for $100.

I trust that the "lemon" business is falling off, and that in future it will be confined to "plums."

Yours very truly,

GENTLEMEN:

I beg to acknowledge your very clever follow up letter asking for my subscription. I lived in Missouri and wish to be "shown." I did not mean to hand you a "green lemon" although it was not as green as one which the former proprietor handed me. I received Compressed Air about six years for nothing. Cost value $6.00.

I furnished one article on the pneumatic tube system of St. Louis which would have brought me $15.00 from Eng. News or Eng. Record.

Just before my article was published, I left the pneumatic tube business. My free copy was stopped and I did not know of the publication of my article till a friend told me. I then wrote the magazine and received 3 copies leaving the account thus:

Green Lemon.....	9.00
Six yrs. subscription.....	6.00
Credit.....	15.00
By one article.....	15.00

How about it?

However I am not prejudiced and enclose check for subscription. I am not new in compressed air business and subscribe because I like your methods.

Yours very truly,

By the way I am not dodgfng any $100 checks.

GENTLEMEN:

Your pathetic or rather urgent appeal Circular of the 3d inst. is received. We find ourselves unable to resist your arguments, and therefore enclose $1.00 which pays for the publication to January 1908.

Trusting that the feverish symptoms will abate on receipt of this, we are,

Very sympathetically yours,

GENTLEMEN:

Enclosed please find check for one dollar which I send you in answer to your letter dated August 3d, 1906, which is, I cannot help remarking, a most remarkable composition. I certainly have never received from you before any request to subscribe, although I have received copies of the paper from time to time, which I understood from a certain source were sent me gratis, and I offered at the time to subscribe in the regular way.

Kindly mail all my communications to my home at 2416 Clarendon Road, Flatbush. Hoping that the enclosed check will obviate any possible repetition of Sherman's verbal explosions, and that you will allow me to express my satisfaction with the general contents of such copies of Compressed Air as I have received from you. I am,

Yours truly,

GENTLEMEN:

I have received your letter of August 3d, and note your distressed condition.

I am going to surprise you by sending you $1.00—this is not so much for the magazine, as for the "Compressed Air" in your letter. I would suggest that if you combine some of the "green lemons" (ripend by this time) which you received, with other ingredients, you might reduce the fever of which you complain.

Yours truly,

¶ It may seem that the above has not much to do with compressed air, but under the heading of Office Chit Chat we enjoy the extreme satisfaction of talking about ourselves and at the same time have an excellent opportunity of extending our apologies to those who may have received one of our War is Hell letters and have as yet been too full for utterance. We qualify our apologies, however, in that they apply only to people who had a legitimate excuse for not having paid their back subscriptions, and we realize that there were many. We apologize to those who acknowledged our letter and sent their subscriptions, the apology in such case, however, being for not sending our letter sooner so as to give them the benefit of subscribing sooner.

¶ To the remainder of our list, those who received our letter, and have not answered it, and have been accepting and reading COMPRESSED AIR without the formality of paying, we extend our greetings and assure them that while their silence may be irritating we cannot but admire their rhinocerous-like indifference to appeals, the preparation of which is so labored and the mailing of which is so painful and yet so necessary.

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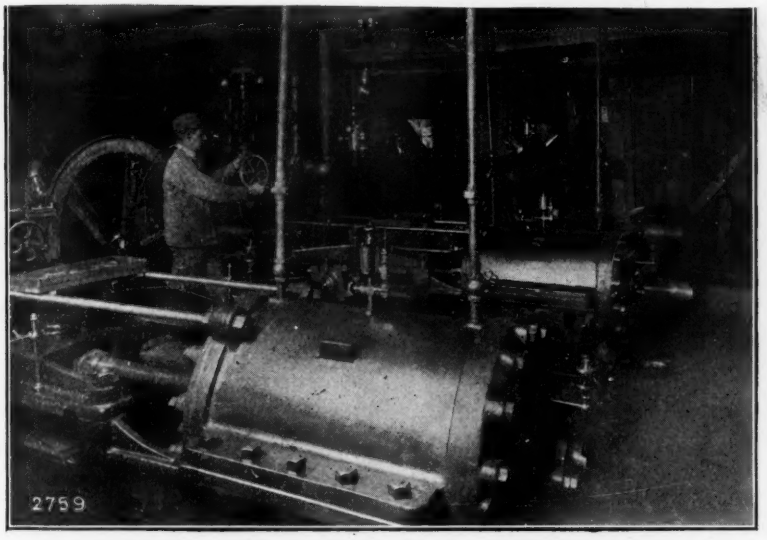

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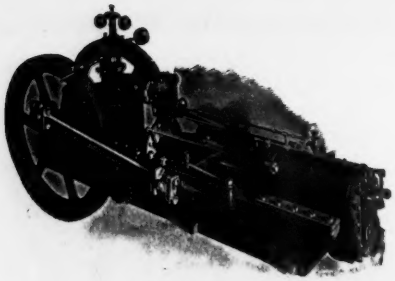

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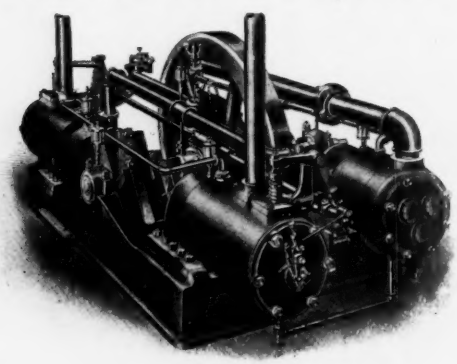

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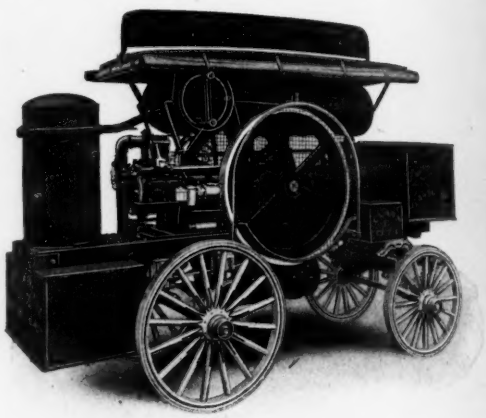

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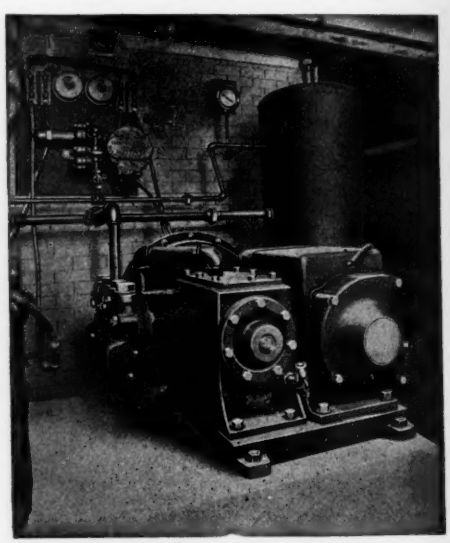

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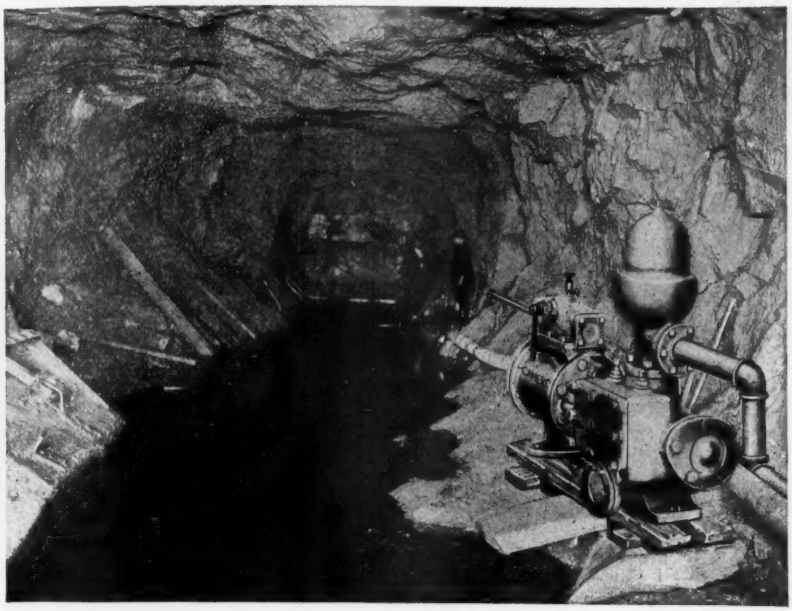

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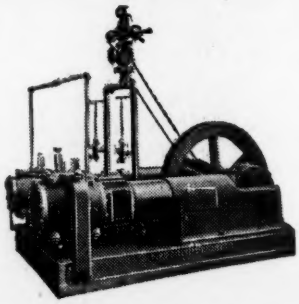

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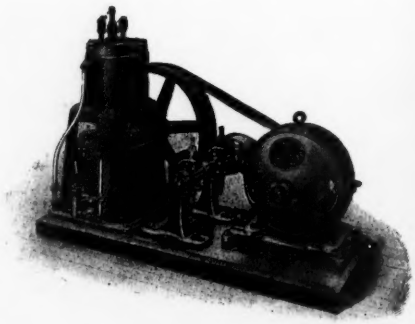

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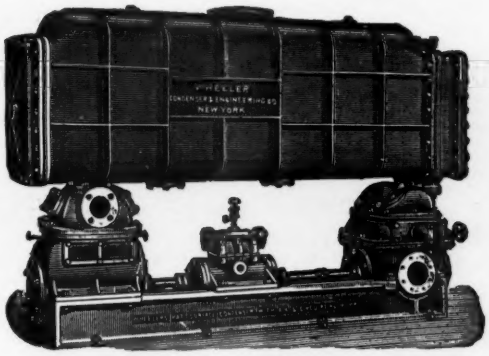

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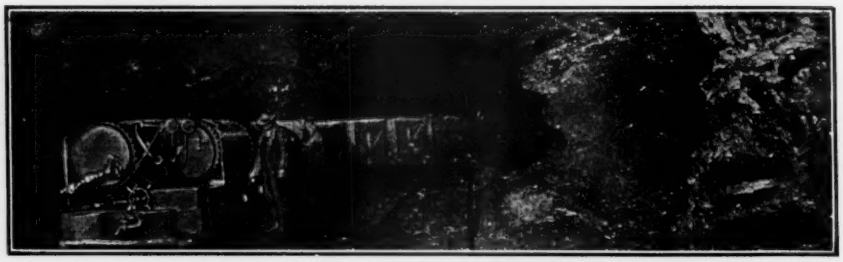

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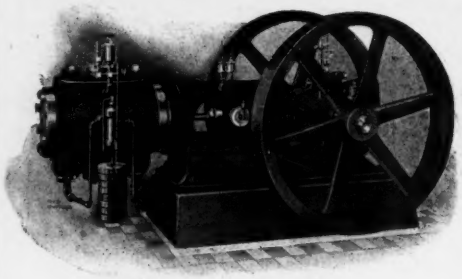

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INDEX TO ADVERTISERS.

Blaisdell Machy Co., The	5
Boiler Maker, The	14
Brown & Seward	5
Browning's Industrial Magazine	18
Bury Compressor Co.	9
Cameron Steam Pump Works, A. S.	3
C. R. R. of N. J.	15
Chicago Pneumatic Tool Co.	Back Cover
Clark Co., The W. J.	Back Cover
Cooper Co., C. & G.	10
Coal	19
Comstock Engine Co.	9
Curtis & Co. Mfg. Co.	5
Davis & Davis	1
Druckleib, C.	5
Engineers' Club	19
Engineering Contracting	1
Engineering News	19
Engineering Magazine	13
Engineering World	16
Engineers' Review	17
Fiske Bros. Ref'g. Co.	Inside Cover
Frasse & Co., Peter A.	11
General Compressed Air House Cleaning Co.	4
General Engineering Co.	4
Goodrich Co., The B. F.	7
Hanna Eng. Works	9
Ingersoll Rand Co.	2 & 8
International Press Cl'p'g. Bureau	18
International Correspondence Schools	13
Lidgerwood Mfg. Co.	Inside Cover
Luce's Press Clip'g Bureau	15
McKiernan Drill Co.	4
Marine Engineering	18
Modern Machinery	18
Mines and Minerals	13
Porter Co., H. K.	7
Powell Co., W. M.	1
R. R. Gazette	14 & 16
Rix Compressed Air & Drill Co.	Back Cover
Romeike Hy.	15
Sargent Steam Meter Co	11
Sprague Electric Co.	Front Cover
Stearns-Roger Mfg. Co.	12
Sullivan Machy. Co.	6
Traylor Engineering Co.	20
U. S. Press Clipping Bureau	15
Westinghouse Trection Brake Co.	4
Wheeler Condenser & Engineering Co.	
Wiley & Sons, John	18

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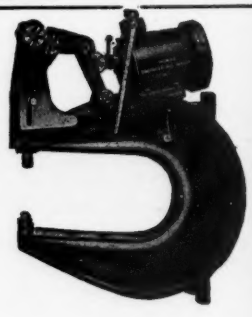

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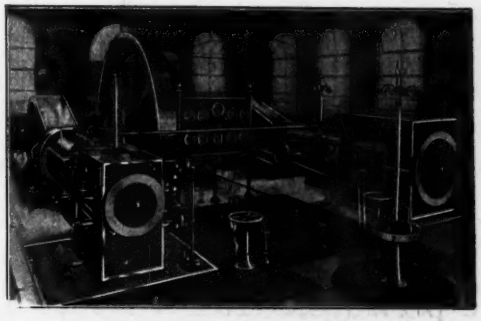

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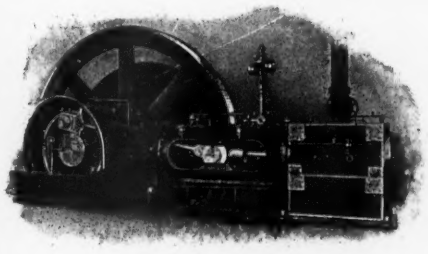

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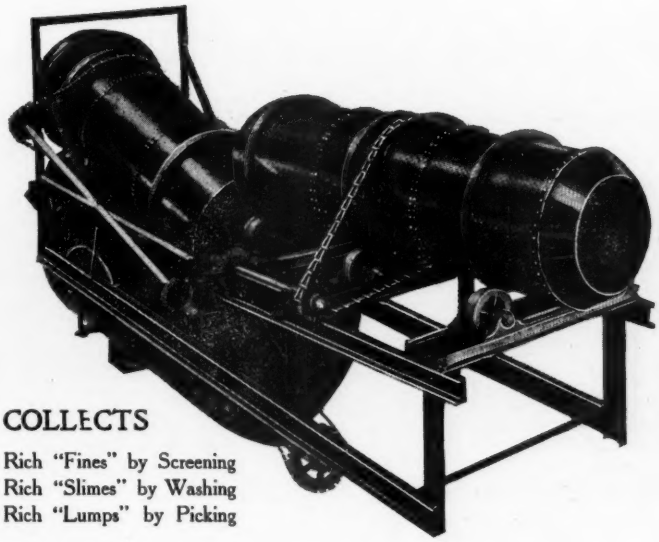

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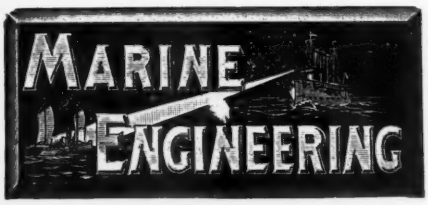

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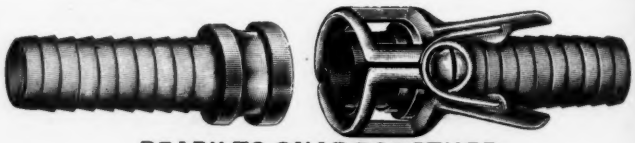

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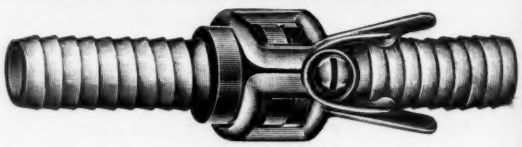

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